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A Dissertation

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

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By

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1998

AIR QUALITY CUMULATIVE EFFECTS ASSESSMENT
FOR U.S. AIR FORCE BASES

A Dissertation APPROVED FOR THE
SCHOOL OF CIVIL ENGINEERING AND ENVIRONMENTAL SCIENCE

BY

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DISSERTATION OVERVIEW

The results of research involving the assessment of cumulative air quality effects are discussed in this dissertation. The dissertation is formatted into seven chapters and four appendices. Chapters 2 through 6 are presented in the style (to include the reference format) of the individual refereed journals to which they have been submitted for publication. However, tables and figures have been numbered to fit the context of this corporate presentation. The appendices present information, pertinent to the research study, that was omitted from the chapters due to journal article length restrictions. Appendices A and B present supplemental information related to Chapter 4. Appendix C presents supplemental information related to Chapter 5. And, Appendix D presents the application study used as a basis for the article presented herein as Chapter 6. Additionally, Chapter 3 appears in the December, 1997 edition of *Project Appraisal*.

ABSTRACT

Federal agencies in the United States are required to consider the cumulative effects (CEs) of their activities combined with those of others. However, improvements are needed in the cumulative effects assessment (CEA) process. Relevant problems and issues identified with respect to CEA include: defining CEs; the focus of the analysis methodology; defining actions which should be included in, or excluded from, analysis; identifying methods, if any, which are available for conducting an appropriate analysis; determining the significance of the predicted effects; and incorporating the analysis results into the decision making process.

This research develops methods and procedures for the assessment of CEs on a specific environmental medium, air quality. The research is targeted for application to the United States Air Force; however, the results are useful to other government agency activities. The analysis components of this research are: (1) a review of recent environmental impact statements (EISs) and environmental assessments (EAs) to identify and evaluate the techniques used to assess cumulative and project-specific air quality effects; (2) a review and analysis of the legal interpretation of what actions are defined as reasonably foreseeable future actions (RFFAs); (3) a review of existing air quality effect quantification models and selection of those that are best suited to CEA; (4) the development of a conceptual approach for significance determination for CEs and associated opportunities for mitigation; and (5) the application of the developed procedures at a U.S. Air Force base.

From the EIS and EA reviews, the lessons learned were used to develop an 8-step Cumulative Air Quality Effects Assessment (CAQEA) method which addresses topics such as past, present, and reasonably foreseeable future actions; emission data estimates for pertinent actions; modeling of quantitative and qualitative changes to background air quality; and significance determinations for air quality CEs.

Consideration of CEs within the environmental impact assessment (EIA) process in the United States involves an analysis of the proposed action in view of past, present, and reasonably foreseeable future actions. Information gathering and analyses related to RFFAs may be the most difficult aspects of addressing CEs. Accordingly, an 8-step Conservative Determination Method is proposed herein for delineating RFFAs for inclusion in CEA.

Air quality modeling provides a scientific means for relating source emissions and atmospheric processes, thus project-related effects on air quality can be quantified using appropriate air quality modeling techniques. A qualitative decision approach applied to a suitability review of numerous classes of models resulted in the identification of three classes that fully meet the criteria requirements for, and desirable attributes of, cumulative air quality effects quantification. These classes are: Simple Area Source, Rollback, and Box models.

A key feature of the EIA process is the determination of the significance of an action's impact in context with its surroundings. An air quality CE significance rating procedure was developed through adaptation of existing EIA significance evaluation methods combined with expert opinion and professional judgment. The procedure includes 18 factors for evaluation relative to specific pollutants and spatial boundaries. A significance score results from the assignment of importance weights and intensity levels to

the 18 factors. Based on the anticipated results of applying the procedure, techniques for evaluating and implementing new opportunities in mitigation are then described.

Finally, a demonstration is provided of the CAQEA method applied from the perspective of an Air Force base's influence on a small southwestern city. This case study identifies the assumptions needed to overcome difficulties in data collection and analysis and the rationale for the decisions made. The result is the development of useful environmental decision making information that can be obtained within the typical time and resource constraints commonly facing assessment professionals.

Chapter 1

Introduction and Literature Review

INTRODUCTION

Problem Statement

Cumulative effects assessment (CEA) has been a required part of the environmental impact assessment (EIA) process for as long as EIA has existed under the National Environmental Policy Act (NEPA). Due to the difficulties in conducting CEA, including: quantification of effects, gaps in the available data, judicial controversy over definitions, and temporal and spatial boundary determinations, impact assessment of cumulative effects has often been labeled as impractical and even impossible. CEA is, however, required by various federal agency regulations promulgated in response to NEPA. Therefore, research into the development of effective, practical assessment methods is needed to provide EIA professionals with the tools they require to comply with the applicable regulations and provide quality environmental protection information to decision makers.

Research Objective

The objective of this research study was to develop a CEA methodology focused on air quality that uses the comprehensive development planning process as a framework for determining spatial, temporal and jurisdictional boundaries. This methodology is not intended to be a final, generic analysis tool that is applicable to all cases, however, it is intended to contribute to the available tools for CEA. To demonstrate its utility, the

methodology was applied to a United States Air Force (USAF) base located in the southwest.

RESEARCH STUDY COMPONENTS

This research consisted of a background literature review (summarized in Chapter 1) and five major components with each component presented as a separate chapter herein. The cumulative effects issues addressed in the five elements are: (1) a review of recent environmental impact statements (EISs) and environmental assessments (EAs) to identify and evaluate the techniques used to assess cumulative and air quality impacts (emphasis was given to U.S. Air Force documents); (2) a review and analysis of the legal interpretation of what actions are defined as reasonably foreseeable future actions (RFFAs); (3) a review of air quality impact quantification methods and selection of methods within that group that are best suited to CEA; (4) the development of a conceptual approach for significance determination for cumulative effects and associated opportunities for mitigation; and (5) method development and testing.

EA and EIS Review

The first research component (Chapter 2) focused on a review of 27 EISs and EAs completed by the United States Air Force. These EIA documents were reviewed with respect to the methods used to assess air quality impacts and cumulative effects, including quantification measures. Attention was given to the emphasis placed on these issues concerning significance determination, level of detail and accuracy of the assessment, and any relationships to programmatic documents. Best practices discovered in the review

process were compiled and summarized as a basis for the development of the 8-step Cumulative Air Quality Effects Assessment (CAQEA) method described in Chapter 2.

RFFAs

The second research component (Chapter 3) was comprised of a review of approximately forty (40) federal and state court cases heard in the United States where rulings were made relevant to the concept of RFFAs. This component incorporated the lessons learned, including contradictions and inconsistencies, from the relevant cases. These lessons were used to develop a systematic list of criteria and an 8-step method which can be used to determine when any possible future action becomes a RFFA. The key questions are related to topics such as: connected actions; linkages of plans and goals, to include regional, city, or base comprehensive plans; proposal definition; and project segmentation. Documentation of the RFFA selection process, due to its inherent uncertainties, is stressed in Chapter 3 as an important part in the facilitation of a responsible EIA process.

Air Quality Modeling

Chapter 4 presents a review of existing air quality impact quantification methods used with various levels of input information availability. Levels of sophistication for the methods selected for review range from simple hand calculations utilizing population equivalencies to project future emission levels to computer models requiring detailed air emission inventory data inputs. A set of criteria was established for the selection of the types of quantification and prediction models, from those found in the literature, needed to determine the cumulative effect of planned future activities. Types of effect quantification

models considered include point, line, and area source emission and dispersion models. The results of this criteria based selection process were applied in the development of a final list of "models", described in Chapter 4, which are appropriate for use under different planning scenarios with varying input data availability.

Significance Determination

Chapter 5 summarizes the development of a conceptual approach to significance determination for cumulative air quality effects. The intent was to develop a rating system to ascertain the cumulative significance of the air quality effects. For the cumulative air quality effects significance determination, multiple criteria are rated and aggregated for an overall interpretation. The resulting significance determination will provide insight on the future state of air quality in the context of the development plans for the area. Based on the results of the significance determinations, possible mitigation opportunities are explored with respect to cost and emission reduction optimization.

CEA Method Application

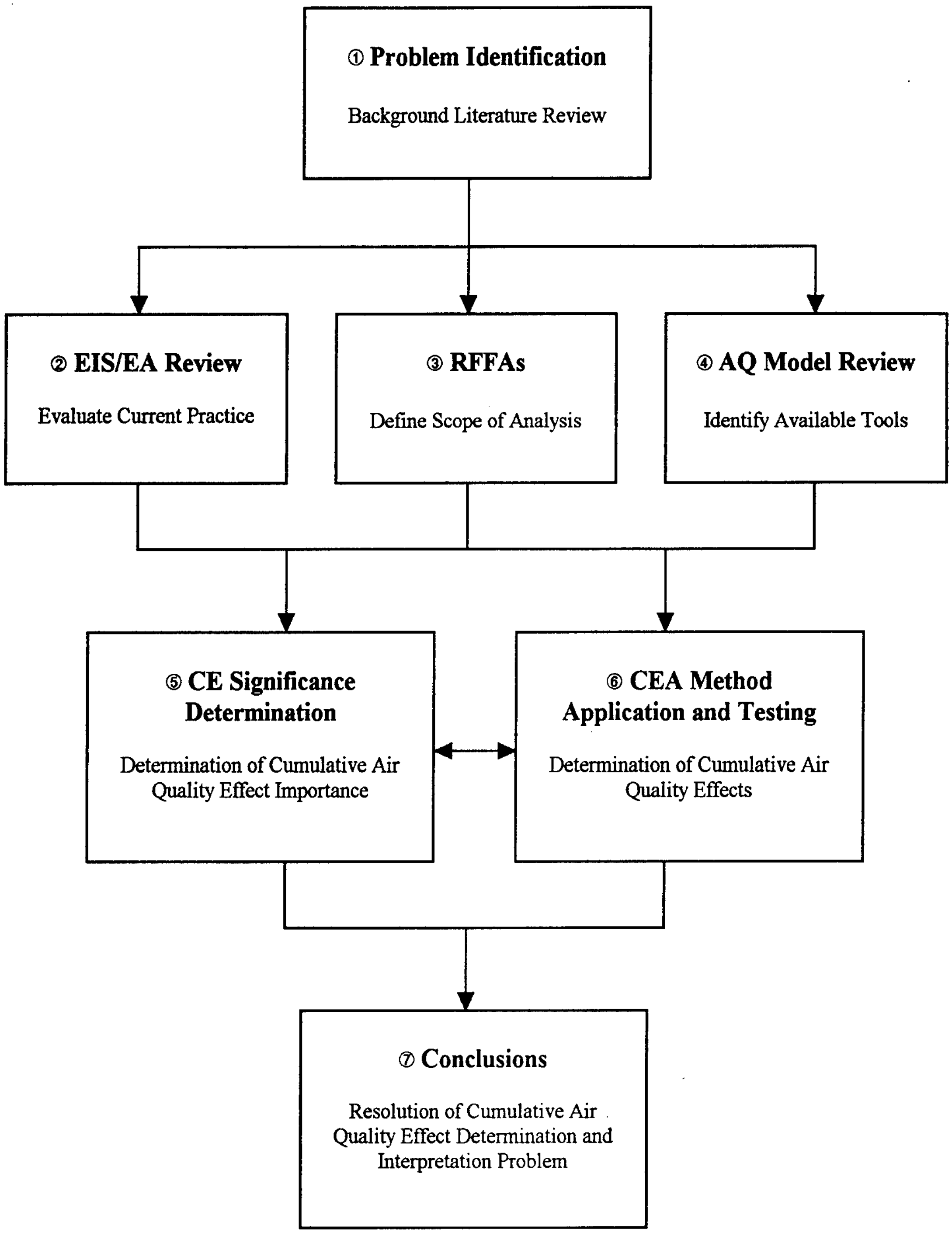
Chapter 6 presents an application of the CAQEA method for cumulative air quality effects assessment developed through the lessons learned and conclusions reached in Chapters 2 through 5. The application is specifically tailored to the assessment of cumulative air quality effects on United States Air Force bases. This application demonstrates the ability of the developed procedures to allow the environmental planner to assess effects with varying degrees of accuracy and level of detail depending on information availability and level of concern about air quality in the study area. All effect quantification

techniques used within the overall impact prediction and assessment method were selected from currently existing, proven air quality quantification models. This was done to facilitate acceptance of the overall methodology into the general practice of preparation of NEPA documents.

An Air Force base located in the southwestern part of the United States was selected for the application. Selection of an appropriate Air Force base included considerations related to: (1) the representative nature of the base, e.g., does it conduct operational or training flight missions; (2) the availability of regional air quality information such as emissions inventories and air quality monitoring data; and, (3) the accessibility to base information including air emission inventories and development planning documents. The potential cumulative air quality effects resulting from actual planned activities at the selected base and the surrounding area were evaluated using the developed CAQEA method.

Dissertation Format

The overall information flow and task linkages for the research study are illustrated by Figure 1.1. As shown in the figure, the initial problem identification was accomplished through a background literature review relevant to the issues associated with cumulative air quality effects determination and interpretation. Issues identified in the literature review are addressed and analyzed in the second, third, and fourth chapters. The review of Air Force EISs and EAs provided insight into the current practice, thus facilitating the refinement of the issues requiring attention as well as the identification of valuable tools already in use that can be adapted for application to the identified problems. The RFFA analysis defines the range of activities to consider within CEA. The review of existing air quality modeling



① refers to chapter number herein

Figure 1.1: Research Flow Chart

techniques identifies the tools that are both available and appropriate for application to cumulative air quality effects assessment.

Chapter 5 addresses significance determination for cumulative air quality effects. This portion of the research provides the decision makers with a mechanism for the evaluation of the importance of the cumulative effects relative to their individual activities and an approach for developing and evaluating available mitigation opportunities. The significance determination approach developed for air quality CEA combines quantitative and qualitative data gathered relative to multiple proposals to provide useful project decision making information in context with surrounding activities.

Combining the information developed in the first five chapters, Chapter 6 presents a practical application at a U.S. Air Force base. This application demonstrates the utility, and relative simplicity, of the developed method and approaches. Finally, Chapter 7 delineates the summary, recommendations, and conclusions from this research.

LITERATURE REVIEW

NEPA Requirements

The National Environmental Policy Act (NEPA) of 1969, which became effective on January 1, 1970, requires federal agencies to consider the environmental impacts of their actions along with the technical and economic evaluations conducted in project planning (Canter, 1996). NEPA states a general policy to restore and maintain the quality of the environment for the welfare of present and future generations and also requires federal agencies to use all practicable means, consistent with other considerations of national policy, to protect the environment (Kamaras, 1993). Section 102 of NEPA contains three main

parts. Part A states that federal agencies must use a systematic, interdisciplinary EIA approach to ensure the integrated use of natural and social sciences and environmental design in planning and decision making that may impact the human environment. Part B requires the identification and development of methods and procedures to ensure that presently unquantified environmental amenities are considered in decision making along with economic and technical factors. Part C indicates the necessity for the preparation of an EIS and identifies the information that should be included (Canter, 1996). NEPA does not, however, make specific reference to cumulative effects assessment (CEA).

The policy provisions of environmental evaluations relative to the protection of the environment for future generations has been interpreted by the Council on Environmental Quality (CEQ) as a requirement for CEA. The CEQ provided a legal mandate for CEA when it issued its regulations for implementing the procedural provisions of NEPA in 1978 (Johnston, 1994). The CEQ regulations require that actions, when viewed with other proposed actions, having cumulatively significant effects be included in the scope of an impact statement. The regulations require the discussion of the cumulative effects of these actions and provide a definition of what effects are considered to be cumulative (Mandelker, 1991). There are four locations within the CEQ regulations where cumulative effects are addressed. The first is where the term "cumulative impact" is defined. The second is within the context of the definition of significance as used for triggering the preparation of an environmental impact statement (EIS). At this location, the regulations include actions which may be individually insignificant but cumulatively significant as sufficient to trigger EIS requirements. The remaining two locations are within the section on defining the scope of an EIS. Here, the regulations require a discussion of "cumulative actions" and also

"connected actions" (Herson and Bogdan, 1991). NEPA, with its resultant CEQ regulations, is not the only regulatory framework in which the need for CEA has been recognized.

State and Other Nation Requirements

Several individual states within the United States have promulgated their own versions of NEPA in order to extend the range of the requirement for EIA beyond the limit of "federal" actions. The Washington State Environmental Policy Act (SEPA) contains language similar to NEPA where it recognizes that citizens have a fundamental right to a healthful environment. The California Environmental Quality Act (CEQA) specifically mentions that the potential for "cumulatively considerable impacts" must be included in the determination of an action's significance. Additionally, the New York State Environmental Quality Review Act (SEQRA), contains general policy guidance similar to NEPA. SEQRA also contains a discussion of the identification and prevention of attainment of critical thresholds for the health and safety of the human population similar to language contained in CEQA (Kamaras, 1993).

In addition to the United States, CEA requirements are included in the EIA process in Canada, New Zealand, and several other nations. In the Netherlands, an amendment to the General Environmental Protection Act (1986) requires that an EIA be conducted for developmental and industrial projects as well as certain plans. The Netherlands system requires that direct, indirect, secondary, synergistic, and cumulative effects be addressed (Couch, 1993). The Resource Management Act, passed by the New Zealand Parliament in 1991 requires the consideration of "cumulative effects over time" within the EIA process

(Dixon and Montz, 1995). And finally, the Commonwealth of Australia has an Intergovernmental Agreement on the Environment. Under this Agreement, all levels of government make efforts to ensure that the planning of all policies, programs, and projects consider sustainable development. "In resource management, the levels of government agree that policy, legislative, and administrative frameworks will include comparable data, the assessment of regional cumulative effects, consultation with effected individuals, and the consideration of significant effects" (Couch, 1993).

It should be apparent, based on the level of national and international regulatory attention, that cumulative effects cannot be ignored in the EIA process. In the United States, cumulative effects analysis has been the focus of legal actions against project proponents. "In the last few years, the courts have been increasingly willing to scrutinize the analysis of the effects of the agency action, combined with other relevant actions, and reject NEPA documents because of inadequate cumulative impact analysis" (Herson and Bogdan, 1991). The CEQ regulations in the United States and the attention received by CEA in the U.S. court system should be an adequate incentive to conduct CEA within the EIA process. However, the attention given to CEA in other nations is also important to note with regard to possible future agreements between the United States and other nations. International agreements on EIA procedural and content issues are already in existence in Europe. The European Council of Ministers developed a directive in 1985 for a community-wide environmental assessment policy. The nations involved were at various stages of development with respect to impact assessment policy, some had no formal EIA legislation, and, the inclusion of transboundary effects was a particularly sensitive issue that was included as a requirement under the directive (Couch, 1993). It is not unreasonable to

assume that, eventually, the United States will enter into agreements with other nations regarding the assessment of environmental effects that will result in impacts across international boundaries. Such an assessment of transboundary effects will necessitate that the cumulative effects of the activities contributing to that transboundary effect are assessed.

For individual federal agencies within the United States, such as the United States Air Force (USAF), it is not so much a question of whether or not a CEA should be done, but one of how to do it. Relevant problems and issues that have been identified include: how should cumulative effects be defined; what actions should be included, or excluded, from analysis; how should the analysis methodology be focused; what methods, if any, are available to conduct the appropriate analysis; and, what do the results of that analysis imply in terms of significance. These topics are addressed in the following sections.

Defining Cumulative Effects

Definition Controversy

The first of these CEA problem areas, the definition of cumulative effects (impacts), has received much attention. There seems to be no one common definition for cumulative effects. This lack of a common definition is largely responsible for the different views on how cumulative effects should be addressed. Johnston (1994) defines cumulative impact as "the incremental effect of an impact added to other past, present, and reasonably foreseeable future impacts" and then later qualifies that statement with a delineation between cumulative impacts and cumulative effects. Johnston states: "Cumulative impacts are the human influences that cause ecological stress, and cumulative effects are the resultant changes." Leibowitz et al. (1992) also differentiate between cumulative impacts and cumulative

effects. The definition they provide for cumulative impact is "The sum of all individual impacts occurring over time and space, including those of the foreseeable future." Their definition for cumulative effects is "The sum of all environmental effects resulting from cumulative impacts" (Leibowitz et al., 1992). The distinction reflects a separation between the scientific assessment of facts (effects), and the evaluation of the relative importance of these effects by the analysts and the public (impacts). This distinction is not officially recognized in the CEQ regulations, however, it is common throughout the literature (Stakhiv, 1988). The CEQ defines cumulative impacts as:

> ...the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR Sect. 1508.7, 1 July 1996)

In reference to effects, the CEQ states:

> Effects and impacts as used in these regulations are synonymous. Effects include ecological (such as the effects on natural resources and on the components, structures, and functioning of effected ecosystems), aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative... (40 CFR Sect. 1508.8, 1 July 1996).

As noted by Sonntag et al. (1987), "each attempt in the literature to define cumulative effects is valid in the context in which it was established." The important aspect of each situation is that there is, in fact, a working definition presented for the context of each application. Since the focus of this study is to develop a usable CEA methodology for the USAF, the most logical definition to use is one that is legally applicable to a United States federal agency. For that reason, the CEQ definition of cumulative impact is used when referring to the assessment method developed in this research.

Application Controversy

Even after the decision is made to conduct assessments based on the specific definition of cumulative impact (effect) contained in the CEQ regulations, controversy still exists as to what cumulative effects or actions actually need to be addressed in the assessment.

> The lack of clearly defined relevant terms and specific operative provisions, and blurred distinctions among the types of impacts in implementing regulations, have resulted in decisions that appear to conflict with the spirit and purpose of the statutes. Agencies, project sponsors, the interested public, and the courts need clearer direction on what cumulative impacts are and when they need to be addressed for the envisioned environmental reviews to fulfill their statutory objectives (Kamaras, 1993).

In the efforts made in the assessment of cumulative effects since the promulgation of NEPA, one of the relevant terms which has found itself in need of clarification or operative guidance is the concept of the "reasonably foreseeable future action (RFFA)." This idea is expressed in several of the definitions for cumulative impact (effect) including the CEQ definition. The definition of RFFA has been the focus of over forty (40) cases brought before U.S. Courts. The decisions made by the courts have often been contradictory leaving environmental assessors with no clarification on what future actions are required for inclusion in an assessment. For example, in one of the leading NEPA cases, *Kleppe v. Sierra Club* (1976), the court held that only those actions that were formally proposed were required to be included in a CEA. The controversy is that court decisions were made before and after *Kleppe v. Sierra Club*, in the cases of *Natural Resources Defense Council v. Callaway* (1975) and *Fritiofson v. Alexander* (1985), where future actions that were not formally proposed were required to be included in the CEA. Ironically, *Kleppe v. Sierra*

Club was still used successfully as a precedence argument as late as 1995. In *Clairton Sportsmen's Club v. Pennsylvania Turnpike Commission* (1995), the Court "clings firmly to the notion that a proposal requiring an EIS is a creature actually pending before a federal agency. Thus if a project is only 'contemplated' or 'less imminent,' it does not merit inclusion in an EIS." This study will attempt to clarify the types of future actions which must be included, and develop a systematic approach for delineating such actions.

Methods and Approaches for CEA

Background and Need

In addition to what actions are to be included, there is also controversy as to how CEA should be approached. Issues to consider include: (1) qualitative versus quantitative analysis; (2) project, resource protection, or environmental media focus for the analysis; (3) level of detail required to provide significant input to the decision making process; and, (4) method availability for accumulation and synthesis of the information desired. The issue discussed previously over a lack of a common definition for cumulative effects points to a larger problem of a general lack of understanding of how cumulative effects should be assessed.

Often, the NEPA planning process must be completed early in the project planning cycle before sufficient design data is available. Evaluating cumulative effects when there is uncertain or insufficient data can be complicated and difficult. Consequently, only a cursory discussion of cumulative effects that does little more than mention the term is often all that is presented. This has little or no value in the decision making process (Eccleston, 1993). Dr. W.A. Ross, a member of the Environmental Design faculty at the University of Calgary,

offers three reasons for the difficulties associated with CEA. They are: "an inadequate understanding of natural and social systems, dissatisfaction with professional cumulative effects assessment work undertaken, and administrative difficulties of cumulative effects assessment" (Ross, 1994). Despite the difficulties in the undertaking of CEAs, the cumulative effect of incremental changes in the environment is recognized as a serious concern that deserves attention.

> The phenomenon of cumulative environmental change and its implications for human society are evident throughout history. The decline of ancient civilizations in Mesopotamia is attributed in part to incremental changes in environmental conditions, particularly increases in soil salinity and sedimentation induced by centuries of irrigation (Spaling and Smit, 1993).

Part of the difficulty in CEA is associated with choosing a method for presenting the incremental effects in a manner that is useful to decision makers when addressing the cumulative significance of an action that, by itself, appears insignificant.

> An analogy provided by Ehrlich and Ehrlich (1981) illustrates this concept. If a single rivet pops out of a jet's wing, no serious threat exists, because no one rivet contributes significantly to the plane's airworthiness. But if enough rivets are lost, the integrity of the plane's structure gradually weakens until a failure occurs. In this analogy, the cumulative effect of the individually minor impacts would be catastrophic (Leibowitz et al., 1992)

Due to the recognition of the impact potential, combined with the resultant administrative and legal requirements, CEA research has received considerable attention over the past decade. However, interest has focused on prediction of additive and synergistic effects on specific ecosystems and little progress has been made on the institutional aspects of CEA. Much of the literature concludes that CEA is too complex and comprehensive to be included in project-specific EIA (Dixon and Montz, 1995).

There are major evaluation and analytical components to CEA implied in the CEQ definition beyond the narrow orientation toward the evaluation of natural systems. These include procedural-legal requirements and the multiple objectives and trade-offs between socioeconomic goals and environmental quality (Stakhiv, 1988). Cumulative effects are a function of the increases in human activities in a given area. As the effects (impacts) increase, the ability to sustain a desirable condition for humans and other species may become questionable. In order to be effective, "the assessment and management of cumulative impacts has to occur at all levels--local, regional, and national, and it has to be an interactive and ongoing process" (Hunsaker, 1995). An institutional framework is needed in which cumulative effects can be addressed in conjunction with project-specific EIAs, yet it needs to be sufficiently holistic to include consideration of the procedural-legal requirements and the socioeconomic goals and objectives of the affected populations.

Before an assessment methodology for cumulative effects can be developed or employed, it is important to understand the ways in which environmental impacts can accumulate. There are two main typologies for categorizing and addressing cumulative effects. The first, developed in a 1986 National Research Council (NRC) report, states that cumulative environmental impacts, or effects, can occur because of (Vestal, et al., 1995):

- **Time Crowded Perturbations** - effects so close in time that the first is not assimilated or dissipated before the second occurs.

- **Space Crowded Perturbations** - effects so close in spatial proximity that they overlap.

- **Synergisms** - different types of effects occurring in the same area that interact to produce qualitatively and quantitatively different responses from the effected ecological community.

- **Indirect Effects** - those produced after or away from the initial activity or transmitted through a complex pathway.

- **Nibbling** - effects of incremental and decremental time and space crowding as well as piecemeal habitat removal.

- **Others** - such as threshold developments which indicate disruptions that fundamentally alter system behavior, time lags, and space lags.

The second typology is based on functional pathways (see Figure 1.2) that can be applied to persistent additions of effects or to persistent losses of material or force (Peterson et al., 1987). These pathway categories overlap with elements of the typology presented by the NRC. In the pathway model, space crowded perturbations, time crowded perturbations, and nibbling are represented in Pathways 1 and 3. Synergisms are included in Pathway 4. Pathway 2 does not directly correspond to any of the categories presented by the NRC. It presents a pathway for biological magnification (Vestal, et al., 1995).

An ideal CEA methodology should thus include the following attributes or components (Witmer, 1985):

(1) It should specifically address multiple projects or activities.

(2) It should be flexible and allow for adaptation to the subject area array of possible site-variable-effect combinations.

(3) It should allow for and be able to incorporate new developments in data collection, analysis, and interpretation.

(4) It should incorporate the analysis of a large geographic region with flexible boundaries.

(5) It should be designed to identify possible developmental activities and effects over an extended time period.

(6) It should specifically address interactions and synergisms and include a way to aggregate effects.

(7) It should incorporate public participation throughout the assessment process.

(8) It should be practical with respect to monetary and time requirements.

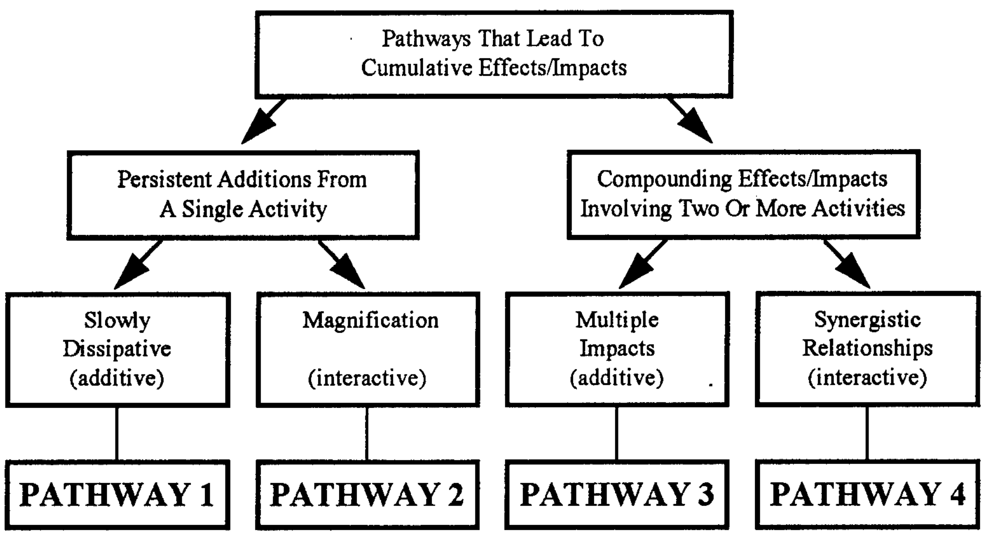


Figure 1.2: Cumulative Impact Functional Pathways (after Peterson et al., 1987)

It may also be helpful for the methodology to incorporate a "tiered" or "clustered" approach to assist in being practical yet flexible (Witmer, 1985). Considerable effort has been expended on the development of CEA methodologies which incorporate these development ideals.

Analysis Frameworks

Several analysis frameworks have been proposed as appropriate mechanisms for the assessment of cumulative effects. "A lack of methods for CIA [cumulative impact assessment] is a recognized problem" (Dixon and Montz, 1995). This does not mean, however, that attempts to resolve this deficiency have not been made. Cumulative effects have been addressed with respect to those generated by a single, specific project or groups of similar projects; further, they have been evaluated as to the effects on a specific resource or environmental media. Such evaluations can be qualitative, quantitative, or a combination of both. Conceptual frameworks for CEA are generally based on a causality model with three components: source of change; process of change; and result of effects (Spaling and Smit, 1993). Additionally, CEA must address interactions of individual effects as well as summarize and synthesize those individual effects over time and space (Nestler and Long, 1994). However, as Irving et al. (1986) noted -- "be forewarned that a generic methodology for the assessment of cumulative impacts does not exist and perhaps never will." "It must be understood that not all environmental components can be subjected to the same analytical approach" (Hydro-Quebec, 1993). This is, in part, due to the difficulty in obtaining relevant information on the effects to some environmental components.

Since the intent is to provide information for better environmental decision making, "the practice of CIA must be focused on realistic outcomes" (Dixon and Montz, 1995). Therefore, important points that need to be incorporated in a CEA methodology include: (1) addressing multiple developments or land use practices; (2) scoping, and a narrowing of the potential effects and affected species and resources to ensure that the method is practical, its results are understandable, and it aids decision making; (3) ensuring the method is adaptable to a large array of site-resource-effect combinations; (4) providing for space and time boundary flexibility; (5) ensuring that the method can aggregate incremental and interactive effects and deal with data deficiencies; and (6) allowing for variable levels of analysis (Irving et al., 1986).

Project Focused Analysis

Analysis methods which focus on individual projects, or groups of projects, include the Cluster Impact Assessment Procedure (CIAP). CIAP was developed by the Federal Energy Regulatory Commission (FERC) to address concerns over the cumulative effects of several small scale hydroelectric development projects. The process incorporates the standard three phases of CEA: analysis; evaluation; and documentation (see Figure 1.3). The CIAP includes several steps: (1) Geographic Scoping; (2) Resource Sort; (3) Multiple-Project Assessment; and (4) NEPA Documentation. The purpose of Geographic Scoping is to identify target resources that could be cumulatively affected by the contributing projects. Target resources are defined as environmental resources that could be adversely affected by two or more proposed projects. The Resource Sort refines the target resource list and identifies resource components. Components are the distinct attributes that

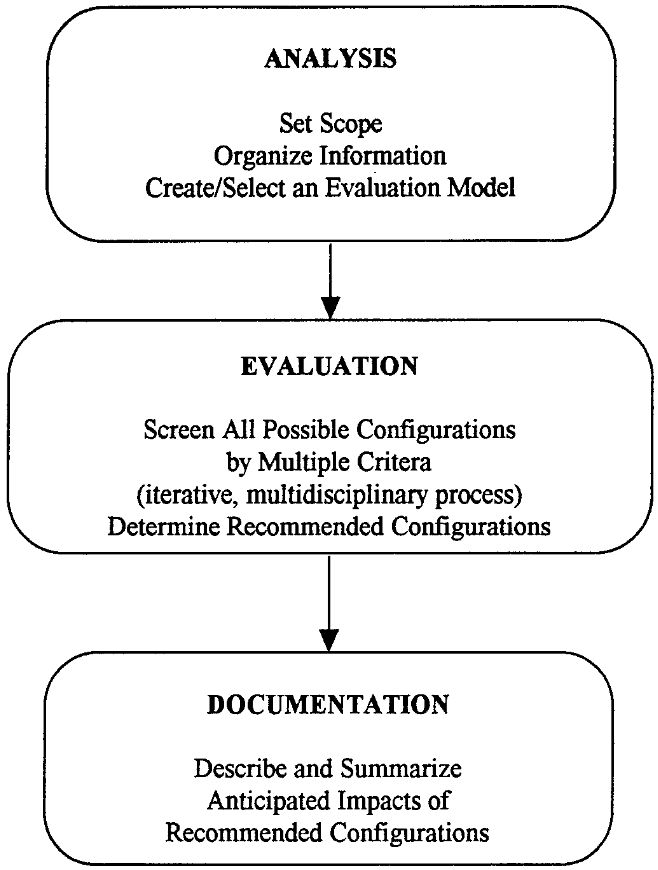


Figure 1.3: General CEA Process (after Bain et al., 1986)

are directly related to the quality of the resource. The Multiple-Project Assessment includes: assigning effect values to resource components; determining interaction coefficients between projects; performing matrix calculations; and determining thresholds (Irving and Bain, 1989). Matrix algebra is used to determine a relative cumulative effect score for each proposed combination of projects. The general equation is (Irving and Bain, 1989):

$$\text{Total Impact} = \text{Sum of Project Impacts} \pm \text{Interaction Impacts}$$

The sum of project impacts (effects) is the additive portion of the analysis determined using a matrix calculation with an importance weighting. The interaction impacts (effects) are determined with a matrix calculation involving the weighted sum matrix from the project impact calculation and a project alternative interaction matrix. The matrix calculation method is graphically presented in Figure 1.4.

One of the weaknesses of the CIAP method was the failure to account for effects from non-hydroelectric activities. Because of this, the method lacks the ability to perform detailed long-term planning (Irving and Bain, 1989). The CIAP was later modified into the Argonne Multiple Matrix method to address some of its shortcomings. Although the analysis method was upgraded, it was still necessary to develop interaction coefficients and determine thresholds for each application. The evaluation did not include non-hydroelectric project effects; however, the analysis did recognize this omission as a deficiency in need of further research (Witmer et al., 1988).

Project focused analysis of cumulative effects that is suitable for long-term planning requires the assessor to have an understanding of the impacts likely from every proposal in the area or region. It also requires the assessor to have available, and understand, assessment methods for each target resource. Figure 1.5 demonstrates the complexity

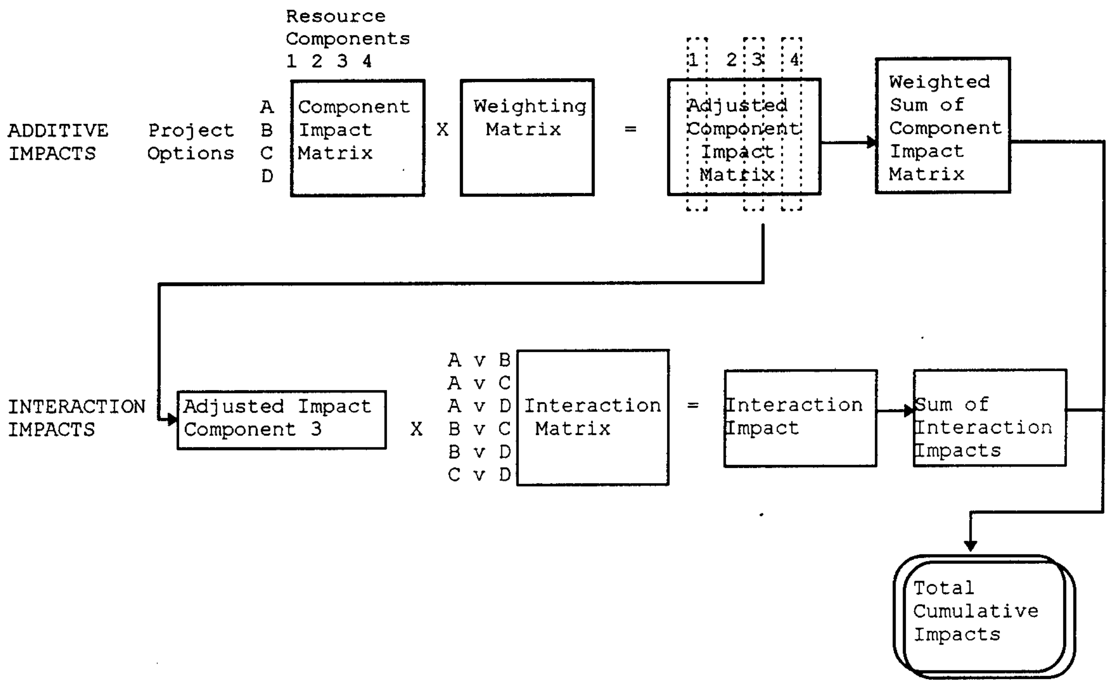


Figure 1.4: Matrix Example for CIAP (after Witmer and O'Neil, 1988)

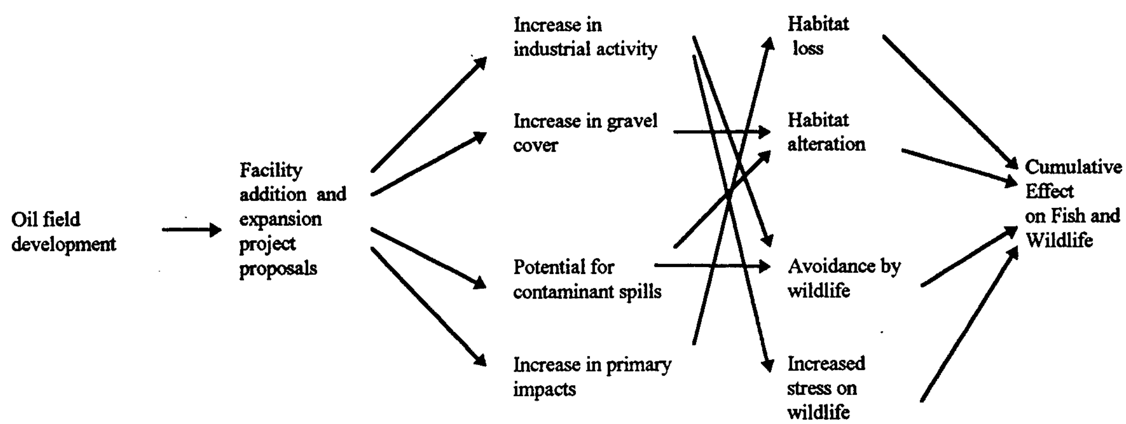


Figure 1.5: Graphical Illustration of a Project Focused Approach to the Analysis of Cumulative Effects on Fish and Wildlife (after Mehan and Webber, 1985).

involved in a project focused analysis. In this figure, only the cumulative effects on fish and wildlife are addressed. A complete project focused analysis would include a diagram such as this for each environmental resource affected.

In the feasibility study for the Grande-Baleine complex, another hydroelectric project, environmental elements identified for CEA were selected with respect to four geographical analysis levels. The relationship between the chosen environmental elements and their corresponding analysis levels were (Hydro-Quebec, 1993):

(1) Territory covered by the James Bay and Northern Quebec Agreement:

- land use
- regional development
- values and perceptions
- caribou
- climate
- mercury

(2) James and Hudson Bay:

- influence of fresh water on the subarctic marine environment
- mercury

(3) North America:

- waterfowl

(4) The planet as a whole:

- biodiversity
- greenhouse gas emissions

The analytical steps used in the Grande-Baleine project assessment were slightly different than those presented in Figure 1.3, however, the analytical complexity was at a similar level. The steps used in this evaluation were (Hydro-Quebec, 1993):

(1) Determination of other projects, whether planned or already completed, which may cause effects to the environmental component in question and which could add to the effects of the Grande-Baleine complex.

(2) Description of the effects of these projects on the environmental component being studied.

(3) Determination of the possible cumulative effects of the Grande-Baleine complex and other projects.

(4) Determination of the applicable mitigative measures.

The complexity of this analysis is significantly increased from that of the CIAP method because it incorporates other, unrelated project effects. For this reason of complexity, impact assessment professionals have developed methods that are tailored to the protection of individual resources or environmental media.

Resource Protection Focused Analysis

Resource protection focused analysis methods include those which are specific to the protection of an individual habitat or habitat type. This type of analysis limits the complexity of the analysis resulting from attempts to assess the effects on all environmental resources and media, as in the project specific analysis, while allowing for inclusion of effects from various sources.

Indices have been used to focus the CEA on a specific environmental resource. For example, by focusing the analysis on the effects to wetlands using hydrologic indices, the assessor can address the interactions of separate, individual effects. The approach described by Nestler and Long (1994) uses hydrologic indices to describe changes in the long-term discharge pattern of rivers. They explain that the indices can be linked to other information

to form cause-and-effect sequences between wetland hydrology, spatial patterns, and functions which, in turn affect habitat value. The method includes simple and complex indices, each with summary variables. The simple method variables include: mean annual discharge; median annual discharge; mean/median monthly discharge; range of discharge; and discharge-duration curves. This approach is attractive to assessors because of its simplicity, however, the indices used are typically not sensitive enough to reveal the subtle shifts in hydrologic patterns that may need to be described in a CEA.

The more complex approach includes a harmonic and a comparative time-scale analysis. The harmonic analysis generates four coefficients-mean, period, phase, and amplitude-that evaluates the fit of a time series of data to describe a process that approximates a harmonic function. This allows the assessor to determine the dominant hydrologic factors, such as groundwater or snowmelt, for evaluating and predicting hydrologic patterns as they are influenced by external factors. The comparative time-scale analysis allows for the assessment of time and scale fractal properties. A system is said to exhibit fractal properties when complex physical features exhibit the same pattern repeatedly over increasingly smaller distances or time scales. The complex approach is more difficult than the simple approach but it is better at revealing subtle changes in hydrologic trends with potential biological significance in the wetland (Nestler and Long, 1994).

An understanding of the hydrology presents one aspect of the cumulative effect mechanisms at work on wetlands. This evaluative technique is limited in that it focuses only on a specific ecosystem, wetlands, and a specific effect mechanism, hydrologic trends. It is, however, applicable to all projects within the boundary area of influence on the wetland selected for evaluation. Also, the method does not incorporate a significance determination

for the wetland effects, thus leaving that particular aspect of the analysis for the decision makers at each application.

The approach presented by Nestler and Long (1994) requires considerable information and resources for use. The USEPA Synoptic Approach to Cumulative Impact Assessment provides a resource protection focused analysis method for cumulative effects on wetlands which is intended for use when time, resources, and information are limited (Vestal et al., 1995). The major steps and substeps of the synoptic approach are outlined in Table 1.1. The synoptic approach provides a broad view of the wetland environment.

> The method is not intended to provide a precise, quantitative assessment of cumulative impacts within an area, nor can it be used to assess the cumulative effects of specific impacts. Rather, it provides a relative rating of cumulative impacts between areas (Leibowitz et al., 1992).

The synoptic approach does not, however, forecast the consequences of allowing a particular development on a particular site since it is not intended to be a predictive model (Vestal et al., 1995). Lacking usefulness in assessing specific effects and the inability to predict future effects severely limits this method's utility as a long-term planning tool.

A landscape approach, developed by Lee and Gosselink (1988), is available for the assessment of cumulative effect phenomena in bottomland hardwood (BLH) ecosystems. The landscape method consists of the following iterative sequence of ecological assessment, goal-setting and planning for implementation (Vestal et al., 1995):

1. **Ecological Assessment** - determining the ecological health of the area through the characterization of cumulative effects on ecological structure and functional ecological processes using landscape indices that integrate ecological processes over large areas;

2. **Goal-Setting** - setting goals for the area environment based on its present health through public consensus based on the assessment and consistent with regulations under the Clean Water Act; and

Table 1.1: Synoptic Assessment Steps and Substeps (after Liebowitz et al., 1992)

SYNOPTIC STEPS	PROCEDURAL SUBSTEPS
1. Define Goals and Criteria	1.1 Define Assessment Objectives 1.2 Define Intended Use 1.3 Assess Accuracy Needs 1.4 Identify Assessment Constraints
2. Define Synoptic Indices	2.1 Identify Wetland Types 2.2 Describe Natural Setting 2.3 Define Landscape Boundary 2.4 Define Wetland Functions 2.5 Define Wetland Values 2.6 Identify Significant Impacts 2.7 Select Landscape Subunits 2.8 Define Combination Rules
3. Select Landscape Indicators	3.1 Survey Data and Existing Methods 3.2 Assess Data Adequacy 3.3 Evaluate Costs of Better Data 3.4 Compare and Select Indicators 3.5 Describe Indicator Assumptions 3.6 Finalize Subunit Selection 3.7 Conduct Pre-Analysis Review
4. Conduct Assessment	4.1 Plan Quality Assurance/Quality Control 4.2 Perform Map Measurements 4.3 Analyze Data 4.4 Produce Maps 4.5 Assess Accuracy 4.6 Conduct Post-Analysis Review
5. Prepare Synoptic Reports	5.1 Prepare User's Guide 5.2 Prepare Assessment Documentation

3. Implementation - planning the implementation of the goals through the development of specific plans, based on landscape structure and function of the area.

Section 404 of the Clean Water Act regulates dredge and fill activities to protect the physical, chemical, and biological integrity of U.S. waters. This system is, however, a reactionary approach to wetland resources in BLH ecosystems. The landscape approach anticipates changes and provides regulatory agencies with a better tool for resource protection decision making. Figure 1.6 summarizes the authors' recommendation for incorporation of the landscape method into the decision making process for Section 404 permits. A critical aspect of the process "is the link between recognition of cumulative effects and regulation of cumulative impacts, as determined through the goal-setting process" (Lee and Gosselink, 1988). A key feature of this method is that a regulatory program is currently in place that can incorporate the method into its operations. It is also notable that, since it is proactive rather than reactive, the method provides a tool for effective future planning.

The Coastal Habitat Evaluation Method is an assessment framework that employs simple calculations, can be adapted to varying environmental quality conditions, and is independent of habitat type. The steps involved in conducting the analysis are: (1) identification of system boundaries; (2) collection of general background data; (3) identification of habitat types within the boundaries; (4) description of habitat attributes; (5) development of regional attribute values; (6) habitat mapping; (7) development of quantitative attribute measures; (8) comparison of attributes in the study area to the expected values; (9) calculation of the total system attributes; and (10) comparison of system attribute totals for each alternative. This analysis method requires considerable

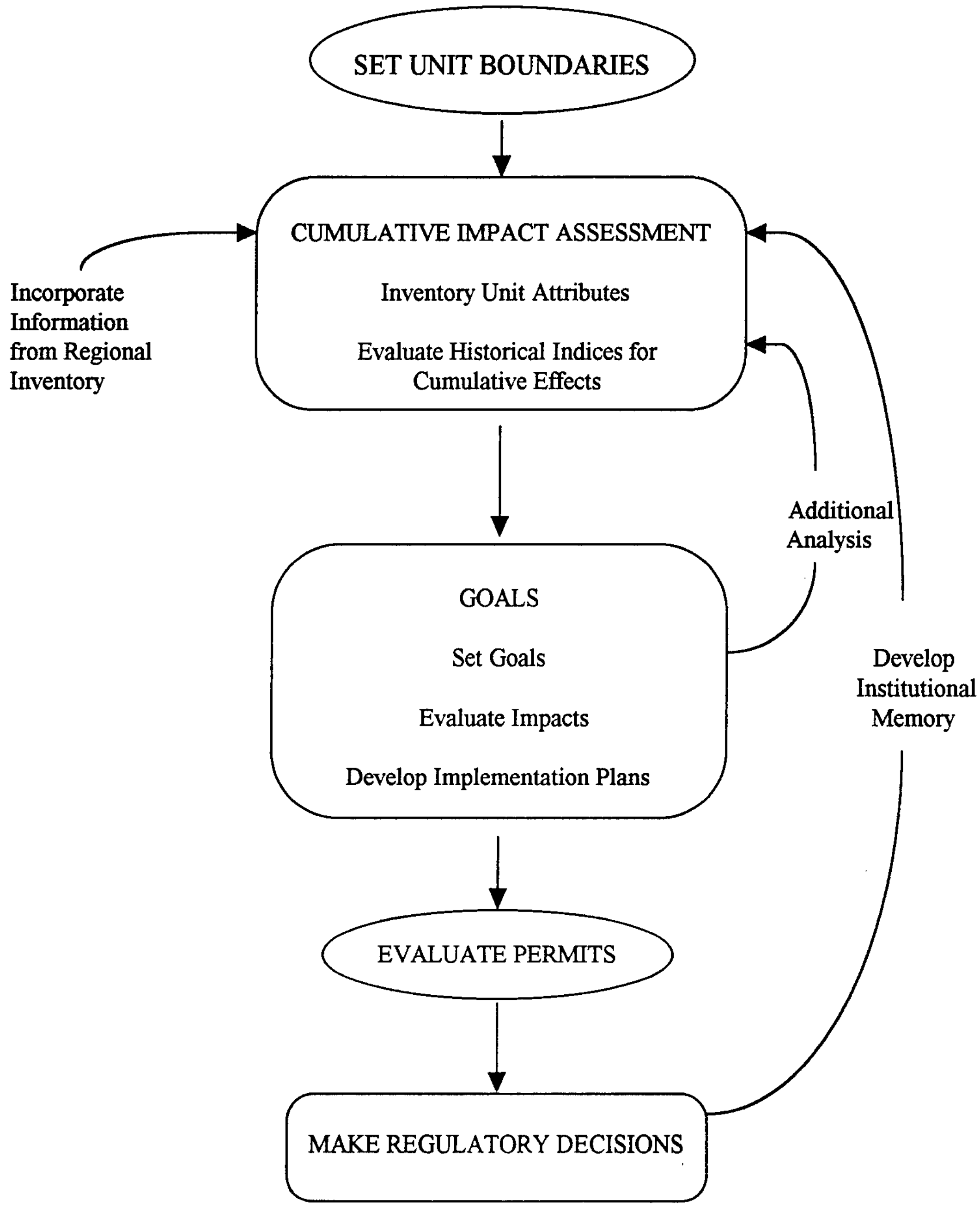


Figure 1.6: Cumulative Impact Assessment Process for BLH Landscapes (after Lee and Gosselink, 1988)

initial effort in the information gathering stage, however, once that is accomplished, it provides a mechanism which allows decision makers to examine system-wide repercussions of activities which effect habitats and their associated attributes.

> [T]he final results can only be applied if there is some common ground among managers regarding the direction in which the system should be managed. These decisions are presently made or negotiated every time there is a new project. Implementation of the new framework can act as a stimulus to formulating a single long-term strategy for managing habitat trade-off issues (Ray, 1994).

Rather than using a new CEA methodology to stimulate the formation of an institutional framework for the incorporation of long-term habitat, or any other environmental resource management, perhaps methods should be developed which can be integrated into existing institutional frameworks which could readily accept CEA.

Regional and City Planning in a CEA Framework

The field of regional and city planning offers an institutional framework in which CEA can be conducted effectively. The comprehensive, or master, plan presents the socioeconomic development goals for the local area under the administrative jurisdiction of one governmental body (So and Getzels, 1988). In fact, regional planning began as a response to cumulative environmental and social effects of industrialization and urbanization and researchers have suggested that it could be used as an institutional context for CEA (Colnett, 1991).

> Development plans are now, more than ever, being prepared with a view toward long-term trends and global issues. The importance of sustainable development is stressed in a wide range of government advice and other guidance, and development plans are seen as one way of implementing sustainability (Thérivel, 1994).

The purpose of CEA is largely to preserve natural resources and the environment for the beneficial use of future generations. That is accomplished through management strategies that preserve, or improve, the integrity of the existing ecosystems of earth.

> Ideally, to maintain ecological integrity, regional planning could provide an area-wide, comprehensive process for evaluating and regulating land-use activities, thereby reducing or mitigating the negative environmental impacts from development (Colnett, 1991).

Therefore, it seems reasonable to use the regional, or area, comprehensive development plan as a mechanism for the identification of existing and proposed projects which would have air quality effects. Since the local government has jurisdiction over the socioeconomic development of the area, identified within the contents of the plan, and the decisions are made with input from the affected public, combining this planning document with a cumulative air quality effect assessment model would improve the information available to decision makers with respect to decisions balancing socioeconomic goals and environmental quality concerns.

Air Quality Focused CEA

To apply a regional based regulatory mechanism to CEA, it becomes apparent that the methods developed for endangered resource protection are too habitat-specific for practical application. What would be more appropriate are methods that could be applied universally across the entire area under the jurisdiction of the regulatory framework. In the example of a comprehensive development plan, this would mean that methods are needed that can be applied to the entire area encompassed by the plan.

A list of cumulative effect issues for CEA was developed for the Canadian Environmental Research Council (CEARC) and presented at the 1993 Alberta Cumulative

Effects Workshop for consideration with respect to the future direction of CEA (Kansas et al., 1994). Table 1.2 presents a summary of the cumulative effect issues, listed in no particular order, that could be developed into media focused assessment tools. As is evident from the list, air quality is a candidate for consideration.

Existing CEA methods have been reviewed by various authors and deficiencies or difficulties have been found. One problem that has been noted about various analysis methods is that quantitative data requirements are often extensive and costly (Damman et al., 1994). An air quality focused analysis would limit the extent and cost of quantitative data requirements since it could make use of existing data collection regulatory requirements, such as air emissions inventories, and could use modifications and combinations of existing USEPA approved dispersion models and emission factors. Application of this type of analysis approach is practical for an agency, such as the U.S. Air Force, that has internal and external directives requiring cumulative effects analysis, comprehensive planning, and air emissions management and modeling.

USAF Requirements for CEA

The USAF provides guidance to its installations as to the proper protection of the environment, how the EIA process should be conducted, and the association between installation developmental planning and the environment. Air Force Instruction (AFI) guidance does not specifically address CEA. It does, however, make reference to requirements to comply with the provisions of NEPA and the CEQ regulations. While there are currently no specific instructions within the AFIs as to how to incorporate CEA into Air

Table 1.2: Categories of Cumulative Effects Issues (after Kansas et al., 1994)

CUMULATIVE EFFECTS ISSUES
1. Long Range Transport of Pollutants
*2. Urban Air Quality and Airshed Saturation
3. Mobilization of Persistent or Bioaccumulated Substances
4. Cumulative Effects Associated with Climatic Modification
5. Man-made Feature Occupation of Land
6. Habitat Alienation
7. Habitat Fragmentation
8. Loss of Soil Quality and/or Quantity
9. Effects of Agricultural, Silvicultural, and Horticultural Chemical Use
10. Reduction of Groundwater Supply and Groundwater Contamination
11. Increased Sediment, Chemical, and Thermal Loading of Aquatic Habitats
12. Accelerating Rates of Renewable Resource Harvesting
*Focus of this research study

Force processes, the institutional framework necessary to incorporate the usage of a cumulative effects analysis methodology is currently in existence.

The AFI on impact assessment procedures, The Environmental Impact Analysis Process, directs compliance with NEPA and the CEQ regulations and emphasizes that NEPA, the CEQ regulations, and the AFI must be used together in order to ensure that EIA is accomplished properly (AFI 32-7061, 1995). While this does not directly mention cumulative effects analysis, it is an implied requirement through NEPA and the CEQ regulations, therefore, in essence, the Air Force is formally directed to conduct CEA on its actions. The AFI also states, "The Air Force should use tiered (40 CFR [sect] 1502.20) environmental documents ... to eliminate repetitive discussions of the same issues and to focus on the issues relating to specific actions" (AFI 32-7061, 1995). Tiering often involves programmatic EIA documents which evaluate the cumulative effects of several projects associated with the program. Programmatic planning documents exist in the Air Force which could be utilized in tiering environmental assessments. In fact, AFI 32-7061 (1995) specifically directs that environmental analyses should be combined with other related planning documents when practicable.

The most obvious Air Force document to combine with programmatic, or cumulative, effects analyses is the base comprehensive plan. The purpose of this plan is:

> To establish a systematic framework for decision making with regard to development of Air Force Installations. Comprehensive planning provides a commander with the information necessary to logically and thoroughly analyze a variety of factors before making a decision that affects the installation or the surrounding community. Comprehensive planning incorporates operational, environmental, urban planning, and other Air Force programs, to identify and assess development alternatives and ensure compliance with applicable federal, state and local laws, regulations and policies (AFI 32-7062, 1994).

The Air Force is required to integrate comprehensive planning with the requirements of NEPA. Prior to making a decision to proceed with a proposal identified in the comprehensive plan, the Air Force must analyze the environmental impacts that could result from implementation (AFI 32-7061, 1995). The process of comprehensive plan development:

> Consolidates related plans and guidelines, regardless of program, related to the management and development of Air Force lands, facilities, and resources into a document that is used to guide future growth and development. This cooperative effort includes all land areas under Air Force control and regions of influence, as well as the current and projected capability of local communities to provide services to Air Force people. The comprehensive planning process includes an analysis of the current, short- and long-range development potential of the installation (AFI 32-7062, 1994).

Considering the requirement to analyze the environmental impacts of a proposal within the comprehensive plan combined with the intention of the plan to manage its resources now and in the future and to project the development potential of the installation, it is not difficult to recognize the importance of and need for predictive models that determine the cumulative effect on available resources. A predictive CEA model for air quality which incorporates the project proposal information available in the comprehensive plan would satisfy the NEPA requirements for air quality cumulative effects assessment and provide additional decision making information about the development potential of the installation.

The Air Force alludes to the requirement to have cumulative effect data on ambient air quality in the Air Quality Compliance AFI (AFI 32-7040, 1994). The major commands are directed to ensure that bases' existing or proposed pollution sources will not degrade ambient air quality. The required demonstration of this may be conducted through atmospheric dispersion modeling. If modeling is the chosen demonstration method, it must

be performed according to EPA regulations and guidance (AFI 32-7040, 1994). Since the base comprehensive plan encompasses all existing and proposed activities within the physical area of the installation, an air quality CEA model should encompass all existing and proposed emission sources and should, therefore, facilitate compliance with this requirement. When determining the appropriate emission control technology to be applied to sources on Air Force bases, the following is directed:

> Perform engineering and economic analyses for each project requiring specification or installation of equipment for control of regulated air pollutants. These analyses will ensure that the selected control technology meets air quality compliance requirements, does not create an unacceptable health or safety risk, and is cost effective (AFI 32-7040, 1994).

Again, an air quality CEA model would provide the information required by this AFI. The assessment of the incremental change in the ambient air quality over time as each proposal was implemented would provide the anticipated ambient concentration of regulated pollutants over the time-frame covered by the comprehensive plan. These concentrations could then be interpreted as to the human health and safety risk presented. Also, the application of control technology could be optimized with respect to efficiency and cost effectiveness based on the predicted concentrations. AFI 32-7040 (1994) requires the Air Force to develop and implement a comprehensive air quality compliance planning program and, when planning a change in emission sources, to coordinate review of the design with the responsible EPA, State, or local authorities as soon as practicable.

It seems, then, that there are existing requirements within the Air Force that justify the need for a CEA methodology or model that predicts air quality effects and there is an existing, internal, institutional framework for linking this model to the base comprehensive plan. The next question, then, is what institutional framework, if any, is available for

coordination with agencies around the Air Force base in conducting a CEA of air pollutant concentrations in an airshed.

The AFI on Interagency Intergovernmental Coordination for Environmental Planning provides the contextual framework in which Air Force planners and decision makers and state or local planners and decision makers can crossfeed information relative to each others activities where those activities would impact the environmental conditions of the other agency (AFI 32-7060, 1994). This guidance includes provisions for transmitting the base comprehensive plan, notably the capital improvements program section, to the pertinent state and local government planning agencies. Memoranda of Understanding (MOU) have been developed to "facilitate exchange of planning and programming information on proposed Air Force, military departments, state, and local and areawide proposed plans, programs, and projects that have potential intergovernmental impacts" (AFI 32-7060, 1994). In an area where there is concern over exceeding the ambient air quality standard for a criteria pollutant, information on area activities resulting in pollutant emissions input into a CEA model would provide a basis for making appropriate development decisions.

Under the MOU template presented in the AFI, the Department of Defense agency agrees to submit information on plans, programs, and projects which have potential impacts on other agency planning objectives (AFI 32-7060, 1994). The types of military department plans and programs subject to the MOU can include: the installation comprehensive plan; Military Construction (MILCON), real property, and housing plans which have been submitted to Congress under the MILCON program; environmental compliance plans; and NEPA documents. State, local, and areawide plans and programs subject to the MOU can

include: environmental, natural resource, transportation, community development, and housing plans and programs as well as local government comprehensive plans. There are also provisions within the agreement to ensure that Air Force planning, environmental, and engineering personnel will meet with their state and local counterparts at least annually to ensure the information provided through the MOU remains current (AFI 32-7060, 1994). These agreements are templates which can be tailored to the specific needs in the local area. The importance of the provisions of AFI 32-7060 to this study is that, once the CEA model has been developed and implemented within the Air Force, the information can be provided to the local governmental agencies for application in their own planning process, if desired, and it ensures that the local area information needed as input to the model is current.

Conformity Requirements

The portion of the Code of Federal Regulations (CFR) that directs the Air Force to conduct environmental impact studies under the Environmental Impact Assessment Process (EIAP) and AFI 32-7061, include a specific reference to special air quality requirements.

> All EIAP documents must address applicable conformity requirements and the status of compliance. Conformity applicability analyses and determinations are separate and distinct requirements and should be documented separately. To increase the utility of a conformity determination in performing the EIAP, the conformity determination should be completed prior to the completion of the EIAP so as to allow incorporation from the conformity determination into the EIAP (32 CFR 989.28).

Conformity refers to ensuring that the air pollutant emissions from a facility, such as an Air Force Base, conform to the requirements of the state implementation plan (SIP), as required under the Clean Air Act Amendments (CAAA) of 1990, for the state in which the facility is located. The federal agency is required to conduct a conformity analysis when it

proposes an action that causes a new violation of National Ambient Air Quality Standards (NAAQS) or contributes, in conjunction with other reasonably foreseeable actions, to a new violation of a NAAQS in a nonattainment or maintenance area in a manner that would increase the frequency or severity of the violation (40 CFR 93.152). A conformity determination is required, except for certain transportation projects subject to 40 CFR 51 Subpart T, for each pollutant where the total of direct and indirect emissions in a nonattainment or maintenance area caused by a federal action would equal or exceed the rates in Table 1.3 or Table 1.4 (40 CFR 93.153). The conformity analysis must be based on the latest planning assumptions available to the federal agency and must be conducted using EPA approved emission models and factors (40 CFR 93.159).

While this requirement does not apply to all Air Force bases, in the cases where it is applicable, the framework of CEA can be used as a mechanism for conformity determinations. The CEA process developed for air quality should include the reasonably foreseeable future activities (actions) available though the latest version of the base comprehensive plan and can incorporate the existing and predicted direct and indirect emissions through inclusion of the emissions inventory coupled with predictive modeling.

Significance Determination

No amount of data collection, modeling, or analysis is valuable to decision making and future planning without a determination of the significance of the information, or impact, to the human community and the biophysical environment. Therefore, any CEA tool that is developed must include a significance determination of the cumulative effects to be useful.

Table 1.3: Conformity Determination Requirement Rates for Nonattainment Areas (after 40 CFR 93.153)

CONTAMINANT	TONS/YEAR
Ozone (VOCs or NO_x):	
Serious Nonattainment Areas (NAAs)	50
Severe NAAs	25
Extreme NAAs	10
Other ozone NAAs outside an ozone transport region	100
Marginal and moderate NAAs inside an ozone transport region:	
VOC	50
NO_x	100
CO:	
All NAAs	100
SO_2 or NO_2:	
All NAAs	100
PM-10:	
Moderate NAAs	100
Serious NAAs	70
Pb:	
All NAAs	25

Table 1.4: Conformity Determination Requirement Rates for Maintenance Areas (after 40 CFR 93.153)

CONTAMINANT	TONS/YEAR
Ozone (NO_x), SO_2 or NO_2:	
All Maintenance Areas	100
Ozone (VOCs):	
Maintenance Areas inside an ozone transport region	50
Maintenance Areas outside an ozone transport region	100
CO:	
All Maintenance Areas	100
PM-10:	
All Maintenance Areas	100
Pb:	
All Maintenance Areas	25

CEQ regulations present three levels of analysis in environmental impact assessment: level 1, categorical exclusions; level 2, environmental assessment (EA) and a finding of no significant impact (FONSI), and; level 3, an environmental impact statement (EIS) (Canter and Canty, 1993). Figure 1.7 shows how the three levels are related. "A categorical exclusion refers to a category of actions that do not individually or cumulatively have a significant effect on the human environment..." (Canter and Canty, 1993). Therefore, the cumulative effects, along with their significance, must be assessed in order to determine first, whether or not they can be categorically excluded and second, as shown in Figure 1.7, whether an EA would lead to an EIS or a FONSI.

Often in CEA, issues that are addressed are screened for inclusion in the study based on their significance in order to limit the magnitude of the analysis. The scoping process can be used for this purpose. Since this research focuses on CEA of a specific resource, air quality, it is important that air quality be recognized as significant within the context of current CEA practice. The U.S. Water Resources Council document, *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, presents a resource significance evaluation that can be applied to the resource of air quality. To be considered in plan formulation and evaluation, the document requires that the environmental resource be significant. Significance is established through institutional, public, or technical recognition of the resource or attribute (Apogee Research Inc., 1995).

Air quality is institutionally recognized through legislation such as the Clean Air Act and its amendments. Table 1.5 presents sources of institutional recognition to consider in this type of significance determination. Significance based on public recognition means that

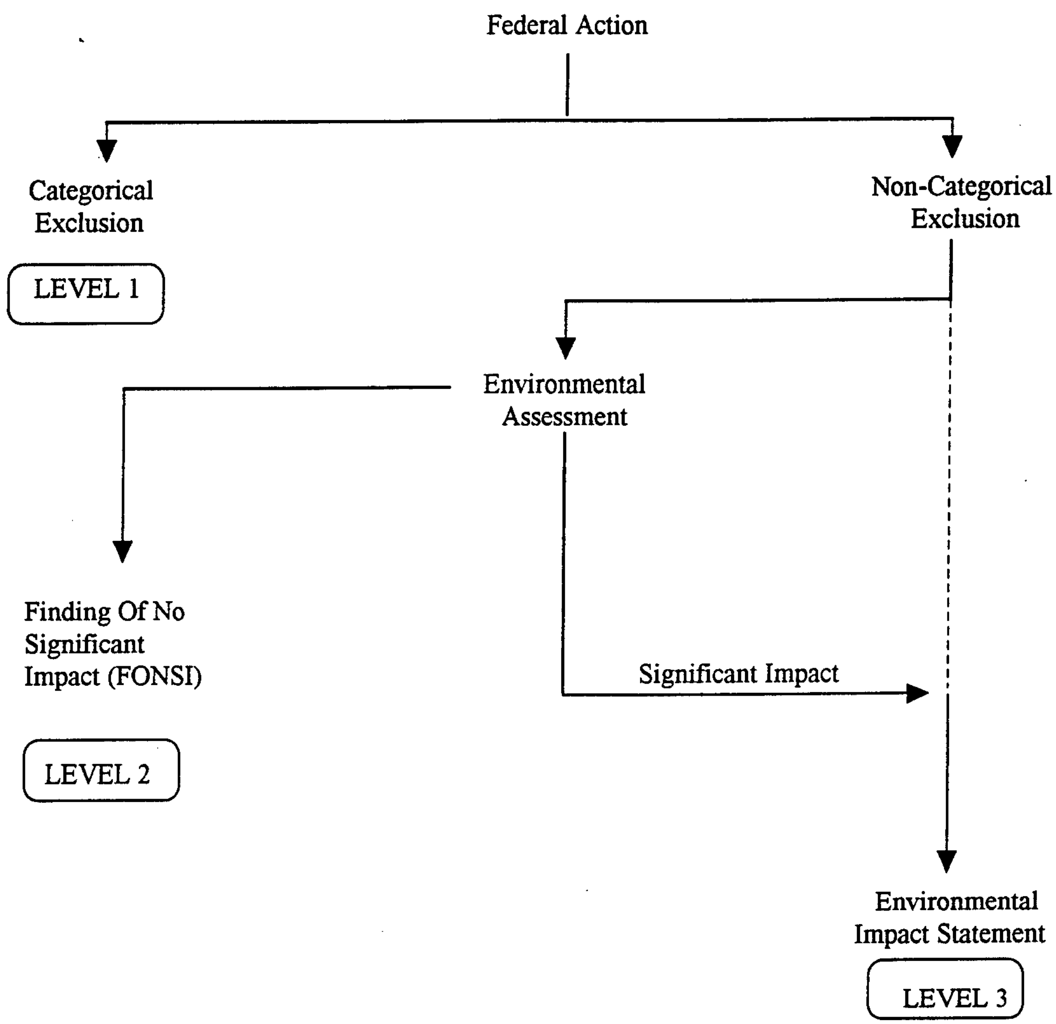


Figure 1.7: EIA Analysis Process Levels (after Canter and Canty, 1993)

Table 1.5: Sources of Institutional Recognition (adapted from Apogee Research Inc., 1995)

Federal	Public Laws, Executive Orders, Rules and Regulations, Treaties, and other policy statements of the Federal government.
State	Plans and Constitutions, Laws, Directives, Resolutions, Gubernatorial Directives, and other policy statements of states with jurisdiction in the planning area.
Local	Laws, Plans, Codes, Ordinances, and other policy statements of regional and local public entities with jurisdiction in the planning area.
Private Group	Charters, Bylaws, and formal policy statements of private groups.

some fraction of the general public recognizes the importance of the resource or attribute. Public recognition may take the form of support, opposition, conflict, or controversy in relation to the effect of the project on the particular resource or attribute. Public recognition can be presented formally or informally (Apogee Research Inc., 1995). Public recognition of the significance of cumulative air quality effects will vary dependent on other competing interests and objectives of the community. The final recognition basis, technical recognition, represents a significance determination based on scientific or technical knowledge or judgment of critical resource characteristics (Apogee Research Inc., 1995).

Once it is established that the significance of a cumulative effect needs to be assessed, and the environmental resource or attribute is perceived to be of significant importance to warrant the time, effort, and money expended on the analysis, it is then necessary to decide how to determine the cumulative effect significance. Significance of an effect refers to both context and intensity. Context means that significance must be analyzed with respect to: society as a whole, the affected region, the affected interests, and the locality. Intensity refers to the severity of the effect (Canter and Canty, 1993). The issues to consider in an evaluation of intensity are presented in Table 1.6.

Significance evaluation needs to address the importance of individual effects, in context, such as an increase in noise or air pollutant emissions, as well as the relative importance of alternative scenarios. An example of a relative importance determination would be an evaluation of the tradeoff between one alternative that had a large effect on air quality and a low noise effect and a second alternative with a large noise effect and a small air quality effect. In determining the intensity of an effect, predetermined threshold criteria should be used whenever available. Ambient standards or environmental quality objectives

Table 1.6: Issues for Intensity Evaluation (after Canter and Canty, 1993)

1.	Impacts may be both beneficial and adverse
2.	The degree to which the proposed action affects public health or safety
3.	Unique characteristics of the geographic area
4.	The degree to which the effects on the quality of the human environment are likely to be controversial
5.	The degree to which the possible effects on the human environment are likely to be uncertain or involve unique or unknown risks
6.	The degree to which the action may establish a precedent for future actions with significant effects or represent a decision in principle about a future consideration
7.	Whether the action is related to other actions with individually insignificant but cumulatively significant impacts
8.	The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register for Historic Places or may cause loss or destruction of significant scientific, cultural, or historic resources
9.	The degree to which the action may adversely affect an endangered or threatened species or its critical habitat
10.	Whether the action threatens to violate a federal, state, or local law or other requirements imposed for the protection of the environment

include inherent significance criteria. Use of these predetermined significance criteria can limit the subjectivity of the evaluation but cannot remove it entirely. When predetermined criteria are not available, significance should be determined through a consensus of the stakeholders in the project. This will serve to limit controversy over the outcome of the significance evaluation (The World Bank, 1996). Significance interpretations differ for cumulative effects in that the significance of multiple projects is interpreted and there is the expectation that combined effects may be significant even though individual impacts are insignificant (Lawrence, 1994). The differences are not so great, however, that the principles used in significance determination for individual impacts cannot be applied to cumulative effects.

Conclusions from Literature Review

Through this literature review it has become apparent that the need for CEA methodology research is valid. There exists national, state, and international interest and regulatory recognition of the need to require the assessment of cumulative effects within the context of environmental protection, resource conservation, and sustainable development. Court cases demonstrate the willingness of the U.S. legal system to enforce CEA requirements, however, there are sufficient gaps in the knowledge base for CEA that court decisions are often contradictory. Most methods currently used in CEA are recognized for their focus on properly evaluating critical environmental resource components as well as for their failings to provide an holistic evaluation. Potential for improvement has been presented through linkages to comprehensive planning and internal Air Force directives requiring CEA. Additionally, the principles applicable to significance determination were included to

ensure that the final product presents a complete assessment tool for cumulative effects analysis on air quality.

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Chapter 2

Air Quality Effects in NEPA Documents -- Project Specific and Cumulative Considerations

ABSTRACT

Federal agencies in the United States are required to consider the cumulative effects (CEs) of their activities combined with those of others. However, improvements are needed in the cumulative effects assessment (CEA) process. Such improvements can be derived from "state-of-practice" reviews. Accordingly, this paper analyzes 27 recent impact study documents prepared by a large federal agency -- the United States Air Force. Specific attention was directed to the cumulative and project specific air quality effects analyses due the volume of stationary and mobile air pollutant emission sources maintained and operated by the Air Force. The lessons learned were used to develop an 8-step Cumulative Air Quality Effects Assessment (CAQEA) method which addresses topics such as past, present, and reasonably foreseeable future actions; emission data estimates for pertinent actions; quantitative and qualitative change to background air quality; and significance determinations for air quality CEs.

BACKGROUND

The National Environmental Policy Act (NEPA) (PL 91-190), in the United States, mandates that federal agencies evaluate and document the environmental impacts of their actions in order to publicly disclose those impacts and, more importantly, to provide decision makers with high-quality information so that they can incorporate that information, and its significance, into the decision making process. One of the requirements specified by

the Council on Environmental Quality (CEQ) regulations is that federal agencies consider the cumulative effects (CEs) of their activities combined with the activities of others (Council on Environmental Quality, 1996). Analysis of such CEs within NEPA documents is a significant challenge to environmental professionals (McCold and Holman, 1995). The challenge stems from the complexity of the cumulative effects assessment (CEA) and confusion, or lack of agreement, on appropriate term definitions and scope of analysis.

The first of these CEA problem areas is the definition of cumulative effects (or impacts). There seems to be no one common definition. This lack of a common definition is largely responsible for the different views on how cumulative effects should be addressed. Johnston (1994) defines cumulative impact as "the incremental effect of an impact added to other past, present, and reasonably foreseeable future impacts" and then later qualifies that statement with a delineation between cumulative impacts and cumulative effects. Johnston states: "Cumulative impacts are the human influences that cause ecological stress, and cumulative effects are the resultant changes." Leibowitz et al. (1992) also differentiate between cumulative impacts and cumulative effects. The definition they provide for cumulative impact is "The sum of all individual impacts occurring over time and space, including those of the foreseeable future." Their definition for cumulative effects is "The sum of all environmental effects resulting from cumulative impacts" (Leibowitz et al., 1992). This distinction is not officially recognized in the CEQ regulations, however, it is common throughout the literature (Stakhiv, 1988). The CEQ defines cumulative impacts (effects) as:

> ...the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such actions. Cumulative impacts can

> result from individually minor but collectively significant actions taking place over a period of time (40 CFR Sect. 1508.7, 1 July 1996)

In reference to effects, the CEQ states:

> Effects and impacts as used in these regulations are synonymous. Effects include ecological (such as the effects on natural resources and on the components, structures, and functioning of effected ecosystems), aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative... (40 CFR Sect. 1508.8, 1 July 1996).

As noted by Sonntag et al. (1987), "each attempt in the literature to define cumulative effects is valid in the context in which it was established." The importance is that there is a working definition presented for the context of each application. Uniform application of a single definition can at least begin to reduce the perceived difficulties.

Even after the decision is made to conduct assessments based on a specific definition of cumulative effect, controversy still exists as to what activities and environmental resources need to be addressed in the assessment.

> The lack of clearly defined relevant terms and specific operative provisions, and blurred distinctions among the types of impacts in implementing regulations, have resulted in decisions that appear to conflict with the spirit and purpose of the statutes. Agencies, project sponsors, the interested public, and the courts need clearer direction on what cumulative impacts are and when they need to be addressed for the envisioned environmental reviews to fulfill their statutory objectives (Kamaras, 1993).

In addition to what to include, there is also controversy as to how CEA should be approached. Issues to consider include: (1) qualitative versus quantitative analysis; (2) project, resource protection, or environmental media focus for the analysis; (3) level of detail required to provide significant input to the decision making process; and (4) method availability for accumulation and synthesis of the information desired.

Often, the NEPA planning process must be completed early in the project planning before sufficient design data is available. Evaluating cumulative effects when there is uncertain or insufficient data can be complicated and difficult. Consequently, only a cursory discussion of cumulative effects is often all that is presented. This has little or no value in the decision making process (Eccleston, 1993).

The lack of suitable methods available for CEA is a recognized problem (Dixon and Montz, 1995). Attempts to resolve this deficiency have been made, however, as Irving et al. (1986) noted -- "be forewarned that a generic methodology for the assessment of cumulative impacts does not exist and perhaps never will." Potential attributes for inclusion in any CEA methodology include (Witmer, 1985):

(1) addresses multiple projects or activities;

(2) allowance for flexibility and adaptation to the array of possible site-variable-impact combinations;

(3) the ability to incorporate new developments in data collection, analysis, and interpretation;

(4) the analysis of a large geographic region with flexible boundaries;

(5) the ability to identify impact and developmental activity possibilities over an extended time period;

(6) addresses interactions and synergisms and incorporates a way to aggregate impacts;

(7) public participation throughout the assessment process;

(8) consideration for resource and time constraints; and

(9) possibly, the ability to conduct "tiered" assessments.

No amount of data collection, modeling, or analysis is valuable to decision making and future planning without a significance determination of the effect on the community and

the environment. Therefore, any valuable CEA method must also include a significance determination step.

CEQ regulations present three levels of analysis in environmental impact assessment: level 1, categorical exclusions; level 2, environmental assessment (EA) and a finding of no significant impact (FONSI), and; level 3, an environmental impact statement (EIS) (Canter and Canty, 1993). "A categorical exclusion refers to a category of actions that do not individually or cumulatively have a significant effect on the human environment..." (Canter and Canty, 1993). The cumulative effects, along with their significance, must be assessed in order to determine whether or not they can be categorically excluded. Also, they must be addressed to accurately determine whether an initial EA leads to a FONSI or an EIS.

Significance depends on context and intensity. As defined by the CEQ, context "means that the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of the proposed action" (40 CFR 1508.27(a) as found in Council on Environmental Quality, 1996). Within the discussion of significance intensity, the CEQ regulations state that consideration should be given to whether "the action is related to other actions with individually insignificant but cumulatively significant impacts" (40 CFR 1508.27(b) as found in Council on Environmental Quality, 1996).

Cumulative effects analysis is essential to effectively manage the environmental consequences of human activities. Thus, the purpose of such an analysis is to ensure that federal decisions incorporate the full range of consequences of actions (Council on Environmental Quality, 1997a).

Improvements to agency applications of the CEA process can result from evaluation of their recent, "real world," analysis efforts against current "state-of-practice" valued ideals. To illustrate, this paper is based upon a review of selected NEPA documents from one federal agency; namely, the U.S. Air Force (USAF).

The USAF is a major component of the U.S. Department of Defense (DoD), the largest U.S. federal agency. The DoD has established environmental leadership as a top priority. It's primary objectives relative to the desired environmental ethic are: the protection of long-term access to resources needed to sustain mission capability; and the enhancement of the quality of life and the environment (Department of the Air Force, 1991).

The USAF was selected due to its stated commitment to the DoD goals for the protection of the environment (Department of the Air Force, 1991) as well as the type and magnitude of its primary activities. Specific attention is directed toward the air quality impacts, both individually and cumulatively. Air quality is of concern to the USAF because of its large, and highly visible, air pollution sources: aircraft and military installations (bases). The USAF maintains and operates approximately 4,500, primarily jet-turbine, aircraft (Mehuron, 1997). The Air Force Civil Engineer Environmental Compliance Division estimates that a typical base has approximately 250 stationary sources that emit an average of 600 tons of regulated pollutants each year (Department of the Air Force, 1995).

Project-specific air quality effects assessment approaches are available that, if followed, include the necessary elements to develop useful decision-focused information. For example, six steps for project-specific air quality effects assessment are shown in Table 2.1 (Canter, 1996). This six-step method outlines the topical mechanics of direct air quality

Table 2.1: A 6-Step Project-Specific Air Quality Effects Assessment Model (after Canter, 1996)

Step 1:	Identification of Air Quality Impacts of Proposed Project
Step 2:	Description of Existing Air Environment Conditions
Step 3:	Procurement of Relevant Air Quality Standards and/or Guidelines
Step 4:	Impact Prediction (technical)
Step 5:	Assessment of Impact Significance
Step 6:	Identification and Incorporation of Mitigation Measures

effects assessment. Similar steps can be developed for cumulative air quality analysis through the evaluation of current air quality analysis applications in context with the problem issues and desirable attributes for meaningful CEA.

To develop improved procedures for CEA of air quality within NEPA documents prepared by the USAF, a systematic review of recent environmental impact statements (EISs) and environmental assessments (EAs) was conducted. A primary repository of publicly releasable USAF documents is the Defense Technical Information Center (DTIC). This repository is the central point within the DoD for storing, acquiring, retrieving and disseminating scientific and technical information to support DoD research, development, engineering, acquisition planing, and studies programs (Defense Technical Information Center, 1996). Of the multiple draft and final EAs and EISs found in this repository, approximately 30 of the most recent final documents were desired for analysis. Nineteen final EISs and eight final EAs were finally selected as the most recent group available; their issuance dates ranged from July, 1989, to March, 1996.

The USAF filed 109 EISs in the six years from 1989 to 1994 (see Table 2.2). In the six years prior to this timeframe, only 41 EISs were filed. The increase could be attributed to a heightened awareness of and concern for the environment and more major action occurrences resulting from base realignment and closure requirements. It is reasonable to assume that the numbers of EISs filed annually from 1994 to 1996 will remain in the range similar to that reported from 1989 to 1994 due to the continued emphasis on the environment and the continuing force restructuring (e.g. base closures). Therefore, the 19 EISs represent an estimated 13% of the EISs filed by the USAF from 1989 to 1996. The 8

Table 2.2: U.S. Air Force EIS Statistics (from Council on Environmental Quality, 1997b).

Year	No. of EISs filed by the Air Force
1983	6
1984	5
1985	7
1986	8
1987	9
1988	6
1989	11
1990	19
1991	20
1992	19
1993	19
1994	21

EAs would represent a significantly smaller percentage of the total USAF EAs prepared in the time interval since an estimated 100 EAs are produced for every one EIS (Canter, 1996). This sample group, therefore, is not intended to be representative of USAF NEPA documents. Rather, it is indicative of the analysis style used by the USAF in their NEPA documents. Table 2.3 presents a summary of the types of actions addressed in the sample group.

The issues found in the literature review are used to frame the analysis of the USAF documents. The problem issues and desired attributes addressed include: the definition of CEs; the scope of analysis employed with respect to activities, environmental media, level of detail, and spatial and temporal boundary range; the method of analysis; and the determination and integration of cumulative effect significance into the overall decision making process. This paper is presented in three main parts: (1) the approach used to evaluate the 27 NEPA documents; (2) the results of the analysis, including a statistical comparison with another recent analysis of CEs treatment in EAs (McCold and Holman, 1995); and (3) a summary of the lessons learned and a resultant proposed method for cumulative air quality effects assessment.

APPROACH USED IN REVIEW

Noteworthy CEA methods or insights currently employed by the USAF might be useful contributions to the cumulative air quality effects assessment state-of-practice.

Table 2.3: Types of Actions Addressed by EISs and EAs in the Sample Group

Action Type	No. of EISs Addressed	No. of EAs Addressed
AFB Disposal and Reuse	14	0
Mission Realignment/Beddown	1	7
AFB Closure	4	0
Facility Construction and Demolition	0	1
Totals	**19**	**8**

AFB = Air Force Base
Beddown = All actions associated with the procurement/construction/modification of equipment and facilities necessary to support the new mission.

Identified deficiencies in these real world applications offer opportunities to suggest improvements to Air Force procedures and refinements to CEA in general.

In general, the analysis is presented as an aggregation of all 27 documents without differentiating between EISs and EAs. This is because CEs must, according to the CEQ, be addressed in both document types. It should be noted that EAs are not intended to be as extensive as EISs; however, it is necessary to include CEA in EAs to properly assess impact (effect) significance. Occasionally, trend data is presented separately for EISs and EAs to illustrate specific points.

Regarding the review of methods for the assessment of air quality effects, several issues were addressed. These included: (1) whether the potential for air quality effects was included in the assessment, and if so, the scale evaluated (e.g., regional or local effects); (2) whether the study determined existing ambient conditions, and if so, how; (3) the quantitative approaches applied, if at all; and (4) effect significance determination.

If air quality modeling, or other quantitative analysis was conducted, efforts were made to determine the attention given to the uncertainty, or inherent error, of the quantitative method. Quantitative modeling can be a powerful tool for impact prediction but its accuracy depends on the accuracy of the assumptions used in model development and application. However, modeling results are often accepted without consideration of the assumptions made in the development of the fundamental equations. The CEQ has stated that one of the strengths of modeling is that it "can give unequivocal results" (Council on Environmental Quality, 1997a). While it is true that other methods may not provide the detail of analysis

afforded by modeling, it is important to recognize that models can produce unequivocally mistaken results. Acceptance of the results from quantitative modeling as absolute fact without consideration of the probability range, indicative of possible error, may lend unjust weight to the model results. Blind acceptance of model results can lead to incorrect decisions as to whether to prepare a FONSI or EIS from an EA analysis. Or, poor decisions can be made regarding mitigation needs or alternative preferences. This is not to say that models should not be used because of the inherent uncertainty factors. Decision makers simply need to understand the true nature of the information provided and make decisions accordingly.

The review relative to CEA first focused on whether or not CEs were addressed. Addressing CEs can range from a brief statement that the potential was considered to detailed evaluation relative to several substantive areas. Determination of the effects that are considered to be cumulative often hinges on the way CE was defined. For that reason, for those documents which addressed CEs, a review was made to ascertain how the impact assessors defined CE. Once that framework was established, the review was based on a series of questions (explained in detail below) to determine the types of actions included in the CEA, the environmental issues addressed, and the methods employed. The evaluation of these issues includes comparisons of the current efforts of the USAF to the ideals presented by Witmer (1985) and the problem issues of definition controversy and significance interpretation. Often it was difficult to determine exactly how the CEs were evaluated; therefore, portions of the statistical analysis on the extent of CEA consideration reflect indications only that "some" type of analysis was conducted. For example, a document may state that, based on the available project information and the existing background conditions,

it was determined that the cumulative effect was minimal. However, no supporting evidence or analysis method is presented with the statement.

The determination and treatment of impact (effect) significance was also addressed. The CEQ requires that the significance of an effect be discussed in a NEPA document. "The analyst's primary goal is to determine the magnitude and significance of the environmental consequences of the proposed action in the context of the cumulative effects of other past, present, and future actions" (Council on Environmental Quality, 1997a). Significance determination for CEs is: (a) required, and (b) linked, but not identical, to the significance of the individual proposal's immediate effect on a specific environmental resource. Our document review, therefore, addressed whether the issue of significance was included for CEs, and if so, investigated the guidelines and/or analytical procedures used to determine significance and incorporate that determination into the decision making process.

RESULTS OF REVIEW -- Project Specific Air Quality Assessment

Before cumulative air quality effects can be evaluated, the air quality impacts of the specific project proposal must be determined. How this air quality assessment is conducted contributes heavily to the information availability for cumulative assessment. All 27 NEPA documents addressed the air quality effects of the proposed action (project) (Table 2.4). In general, the results indicate that the USAF is fairly comprehensive and consistent in the evaluation of project-specific air quality effects. All 27 documents provided some indication

Table 2.4: Statistical Summary of Project Specific Air Quality Effects Evaluation

Sample: 8 EAs and 19 EISs		Total	27
Addressed Air Quality Effects		27	(100%)
Spatial Scale Evaluated:	Regional Only	5	(19%)
	Local Only	2	(7%)
	Regional and Local	20	(74%)
Ambient (Background) Pollutant Concentrations Determined		21	(78%)
Type of Analysis:	Qualitative Only	3	(11%)
	Included Some Quantitative	24	(89%)
If Quantitative Analysis Conducted (24 documents), Provided Discussion of Quantitative Method Uncertainty:			
	Directly Discussed	0	(0%)
	Indirectly Implied	7	(29%)
	No Mention of Uncertainty	17	(71%)
Addressed Significance of Air Quality Effects		27	(100%)
Guidelines or Analytic Method Used to Determine Significance:			
Comparison to AAQS* with Listed Decision Criteria		11	(41%)
Comparison to AAQS without Listed Decision Criteria		4	(15%)
Relative or % Change in Emissions (no scale given)		5	(18%)
No Listed Guideline or Method		7	(26%)
Included Statements of "Significant" or "Insignificant" when Discussing a Specific Effect		11	(41%)
Provided an Explanation of How Air Quality Effects Significance was Interpreted and Incorporated into the Decision Making Process		0	(0%)

*AAQS = Ambient Air Quality Standards

that the effect significance was determined. Twenty-four of the documents (16 EISs and 8 EAs) included some type of quantitative analysis of the pollutant emissions resulting from the proposed activities. Twenty-one (16 EISs and 5 EAs) obtained regional air quality monitoring data for use in comparison of with- and without-project conditions. In 20 of the documents reviewed (16 EISs and 4 EAs), air quality impacts were evaluated on both regional and local scales.

The dominant quantitative analyses included atmospheric dispersion modeling (15 documents) and emissions estimations (20 documents), with several documents including both types of analyses. Table 2.5 presents a summary of the utilized models; each type of model is used in environmental impact studies and in air quality management programs (United States Environmental Protection Agency, 1993). Some studies incorporated multiple models into the analysis. Fourteen of the 15 studies where atmospheric dispersion models were used were EISs prepared for base disposal and reuse activities. This activity type consistently addressed more alternatives (e.g., civilian airport development and residential, commercial, and industrial expansions), with their associated diversity of activities, than the other action types. Base disposal and reuse also represents a more extensive activity than a mission realignment/beddown or facility construction activity. No alternatives to the proposed action were considered for base closures, consistent with the Base Realignment and Closure Act of 1988.

Table 2.6 presents a synopsis of the application of emission estimation in the 27 documents reviewed. When compared to the Table 2.5 results, incorporation of emission estimation techniques was found to be slightly more encompassing than that of modeling.

Table 2.5: Air Quality Model Usage for Project Specific Effects

Model	No. of EISs	No. of EAs
Emissions and Dispersion Modeling System (EDMS)	13[a]	1[b]
Mobile Source Emissions Model (MOBILE)	3[a]	0
Screening Procedures for Estimating the Air Quality Impact of Stationary Sources (SCREEN)	2[a]	0
Industrial Source Complex Short-Term (ISCST)	1[a]	0
Graphical Input Microcomputer Model (GIMM)	1[a]	0

[a]AFB Disposal and Reuse Action
[b]Mission Realignment/Beddown Action

Table 2.6: Emission Estimations Related to Action Type[1]

Action Type	No. of EISs Estimating Emissions	No. of EAs Estimating Emissions
AFB Disposal and Reuse	14/14	N/A
Mission Realignment/Beddown	1/1	4/7
AFB Closure	0/4	N/A
Facility Construction and Demolition	N/A	1/1
Totals	**15/19**	**5/8**

[1]Emissions estimates accomplished through a combination of methods and emission factors presented in:

Fagin, G.T. (1988) "Manual Calculation Methods for Air Pollution Inventories," USAF Occupational and Environmental Health Laboratory, Brooks AFB, TX.

Seitchek, G.D. (1985) "Aircraft Engine Emissions Estimator," Tyndall AFB, FL.

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However, the four base closure documents did not incorporate these techniques. One possible explanation for this omission is the realization, by the assessors, that a comprehensive, quantitative air quality analysis would be included in the follow-up disposal and reuse EIS prepared for each closed base. Another possibility is that the emission reduction resulting from base closure is beneficial and therefore cannot have a significant adverse effect. However, when evaluating intensity, the CEQ states that a significant effect may exist even if the agency determines that, on balance, it is beneficial (Canter and Canty, 1993). Also, the Base Realignment and Closure Act exempts the Air Force from the requirement to address alternatives. It does not exempt the Air Force from the requirement to address the environmental consequences of the proposal.

The 24 documents that incorporated quantitative predictions were studied to determine if the uncertainty, or possibility for error, in the methods employed was addressed. None of the reviewed documents directly addressed the level of uncertainty, or error factor, associated with the method used. Seven documents indirectly implied that uncertainty was included. These discussions, related specifically to the use of atmospheric dispersion models, involved explanations of the use of the models to conduct conservative, "worst-case," analyses. Using of the most unfavorable atmospheric inputs implies that any difference between the predicted and actual concentrations would be such that the error would indicate higher pollutant concentrations than would actually occur. This does not specifically address the probability range of actual concentrations relative to the predicted value; however, it does provide the decision maker with a crude frame of reference for evaluating the consequences of the activity. Worst-case analysis is generally accepted

practice in project specific analyses. However, worst-case condition model results still include error resulting from the inherent model assumptions. In a cumulative sense, multiple activity effects aggregated over time can increase this error. De Jongh (1988) offers multiple approaches for handling uncertainty. A partial list is presented in Table 2.7. The remaining 17 studies did not discuss uncertainty.

An air quality effects significance determination was included in all 27 documents. Fifteen based the determination on a comparison with relevant ambient air quality standards (AAQS). In eleven of the 15 studies, the following additional criteria stated that effects were considered to be significant if emissions would: (1) cause or contribute to a new off-site violation of a federal, state, or local AAQS; (2) increase the frequency or severity of existing violations; (3) delay timely attainment of the AAQS for ozone or any other required emission reduction goal; (4) interfere with efforts to be in attainment with pollutant standards other than those for ozone; and/or (5) expose sensitive receptors to substantial pollutant concentrations. In general, these criteria can be interpreted to mean that effects are considered significant when there is opportunity for the activity to exceed legally defined limits or create nuisances.

Five of the documents reviewed determined significance through a discussion of the percent change in total emissions in the local or regional area. No scale or threshold was specified as to what percent change would constitute a significant effect; however, use of percent change can be valuable when addressing the context aspect of the significance determination. This method would be useful when the raw emission tonnage is low enough not to trigger major source requirements in an area with low pollutant concentrations. The remaining seven documents did not identify any guidelines or methods used for significance

Table 2.7: Approaches for Handling Uncertainty (after De Jongh, 1988)

INPUT UNCERTAINTY	
Technique	**Objective**
Measurement and Analysis	Select measurement and analytical methods necessary to achieve desired level of accuracy in terms of data bias and imprecision
Sampling Program Design	Design sampling program in terms of size, frequency, location, and randomness to obtain desired level of detail
Sensitivity Analysis	Identification of inputs that contribute most to error and focus efforts on improvements in those areas

PREDICTION UNCERTAINTY	
Technique	**Objective**
Scenario Approach	Predict a range of possible outcomes taking into account input uncertainty
Monte Carlo Simulation	Predict the probability distribution of possible outcomes taking into account input uncertainty
Constrained Parameter Approach	Predict the probability distribution of possible outcomes under different scenarios taking into account input uncertainty
Expert Systems	Make predictions from a basis of understood lack of knowledge and data using system behavior rules defined by "experts"

determinations. In these cases, qualitative statements were included of significance/insignificance, or else insignificance was implied by the preparation of a finding of no significant impact (FONSI).

The significance of an effect from the proposed action or one of the alternatives, once determined, should be incorporated into the overall decision making process as well as mitigation measure identification and selection. Unfortunately, no mechanism for directly comparing the significance of air quality effects against other effects was documented in the sample group used for this study. It was apparent, however, that the effects-related information was intended to be presented to decision makers in a format to facilitate comparisons. The standard format for most of the documents reviewed presented all effects in a summary table with media affected listed as the row titles and action alternatives listed as the column titles.

Finally, the air quality effects section of each document included some discussion regarding mitigation. These discussions typically addressed immediate, or "construction", activity mitigation and operational, or long-term, mitigation opportunities. Since direct effect mitigation, via reduction in pollutant emissions, will also help alleviate CEs, it could be surmised that CEs mitigation was included by default. The mitigation discussion was generally presented in the documents after both the project-specific and CEs were discussed. However, none of the documents included a separate section on CEs mitigation. With specific consideration of CEs mitigation, the assessors have the opportunity to facilitate mitigation efforts by considering a broader range of options involving other present and

reasonably foreseeable future actions. Integrated planning for the mitigation of CEs is a problematic issue in CEA.

RESULTS OF REVIEW -- Cumulative Effects Assessment

The CEA application analysis began with an investigation into the level of understanding demonstrated in the documents of how to conduct a meaningful analysis. Of the 27 NEPA documents evaluated, 24 at least mentioned the issue of CEA. The summary statistics are presented in Table 2.8. One of the difficulties with CEA is the lack of a common definition, or common understanding, of what, exactly, comprises a CE. This particular problem was identified early in the evaluation of the 27 documents. The 24 relevant documents were examined to determine if a definition of a cumulative effect (or impact) was included. Four quoted the definition provided by the CEQ. This definition is appropriate for use within the United States since it is presented in a legally enforceable government regulation. One document defined cumulative effects (impacts) as the "combined impacts resulting from all activities occurring concurrently at a given location." This glossary definition does not seem to include consideration of past and future activities and, therefore, may leave the document more vulnerable to legal challenge. This definition, and its application is, however, preferable to no CEs consideration. Six of the 24 documents did not include any definition of CEs; however, they did include some CEs discussion.

Thirteen documents contained both the CEQ definition and the glossary definition presented above. The CEQ definition was included in the text at the introduction to the

Table 2.8: Statistical Summary of Cumulative Effects Evaluation in the Study Group

Sample: 8 EAs and 19 EISs	Total	27
Mentioned the Term "Cumulative Impact" (or Effect)	24	(89%)
Of Those That Mention CE, How is CE Defined (of 24)		
No Definition Provided	6	(25%)
CEQ Definition	4	(17%)
Glossary of Terms Definition (other than CEQ def.)	1	(4%)
CEQ Def. and Glossary Def. both Listed in Document	13	(54%)
Were Potential CEs Identified		
Identified the Potential for CEs (of 27)	19	(70%)
- Identified Potential for **ALL** Affected Media	7	(26%)
- Provided Discussion/Analysis of Potential CEs for All Affected Media	4	(15%)
- Identified Potential for and Discussed CEs for **SOME** Affected Media	12	(44%)
Actions Addressed in CEA (of 19)		
- Past: USAF	1	(5%)
Other Agency	0	(0%)
- Present: USAF	1	(5%)
Other Agency	0	(0%)
- Reasonably Foreseeable Future:		
Proposal and Alternatives Only	4	(21%)
Other USAF	6	(32%)
Other Agency	9	(47%)
Stated Conclusion of No CEs Without Supporting Evidence or Analysis (of 27)	5	(19%)
No Statement Made in Document About CEs (of 27)	3	(11%)
Included Statements of "Significant" or "Insignificant" when Discussing a Cumulative Effect (of 27)	12	(44%)
Provided an Explanation of How Cumulative Effect Significance was Interpreted and Incorporated into the Decision Making Process (of 27)	0	(0%)
Discussed Irreversible and Irretrievable Resource Commitments (of 27)	11	(41%)

section on environmental consequences, and the alternate definition was provided in the glossary. Because of the differences, the potential for CEs to be treated in a non-uniform manner is increased.

Several cases where the definition, or intent, of CEs appeared to be misapplied or completely misunderstood were also identified. For example, in one document, a CE was determined to be the addition of an adverse impact on one media to a beneficial impact on another media to result in a mathematical cancellation which produced no CE. Another document addressed the ability to continue with the USAF mission despite the project impacts generated.

Of the 24 documents that mentioned CEs, nineteen identified potential CEs as a result of the contemplated action. The other five contained statements that no CEs would result from the proposed action or its alternatives; however, no documentation was provided.

As with any NEPA document, some type of exercise was typically conducted to identify and select the affected environmental media or resources for inclusion in the analysis of environmental consequences. Of the 19 documents that identified the potential for CEs as a result of the intended activity, seven addressed potential CEs relative to every environmental medium or resource identified through the initial scoping process and included in the project-specific effects assessment. Four of these documents contained in-depth discussions of the analysis of the potential CEs.

The remaining 12 documents that identified the potential for CEs included discussions on only selected environmental media or resources with no explanation of the exclusions. Five of the 12 further limited their discussion of CEs by dismissing the effects relating to some media as insignificant without providing any discussion or analysis. Three possible explanations for this treatment of CEs are: (1) where specific media or resources were excluded from CEs discussion, a scoping activity was conducted which eliminated them; (2) these potential CEs were eliminated due to study constraints such as time, money, and available information; or, (3) the exclusions were the result of a lack of understanding of CEA procedures or the importance of CEs. Since no explanation was given, no clear delineation of the selection/exclusion process could be ascertained from the written documents. If the effect to an environmental resource is determined to be so insignificant in an initial scoping exercise as to be eliminated from direct project effect analysis, than omission of CE considerations may be reasonable. However, when the determination is made that a direct project effect merits analysis, it seems reasonable that its cumulative effect on the surrounding region should be evaluated.

Of the 19 documents that discussed and analyzed CEs, 12 included statements as to their significance. No guidelines were provided in any of the documents as to how the significance was determined. The 12 cases simply included statements within the CEs discussion section that the effects were insignificant. However, four cases were noted where the CEs were either incorporated into the individual project effects discussions prior to any significance determination, or the CEs were listed with the individual project effects in summary tables. But, even in these cases, no mention was made as to how the CEs were interpreted and incorporated into the decision making process. If the significance of the CEs

are not included, the cumulative assessment portion of the analysis does not contribute to informed environmental decision making.

The approach for addressing past, present, and reasonably foreseeable future actions was also examined in the 19 documents. This addresses the scope and level of detail of the CEA efforts. Only one document considered the effects from a specific (USAF) past activity, and only one other included a discussion of the effects from a specific (USAF) related present activity. None of the documents included other agency past or present activities, however, it can be argued that the determination of the ambient pollutant concentration without the contemplated action effectively includes contributions from past and present activities both internal and external to the subject agency.

The study results suggest that greater consideration was given to the inclusion of reasonably foreseeable future actions. Only four documents limited the discussion of future activities to the proposed action and its alternatives. Six cases included additional USAF contemplated actions, and nine included contemplated actions proposed by other agencies, including non-federal agencies. Commendably, one document out of the nine used regional development planning documents to compile the reasonably foreseeable future actions for inclusion in the analysis.

The requirement to address the irretrievable and irreversible commitment of resources is included as part of the CEQ requirement to discuss the environmental consequences, to include their significance, of a proposed action (Council on Environmental Quality, 1996). Eleven studies included a section on irretrievable and irreversible commitment of resources. This section was found separate from both the project effects and

CEs sections. The issue of concern is the separation of resource assessment from other aspects of the assessment. If significance was addressed in this section, typically, the discussion concluded that the resource expenditure was relatively small in comparison to the available supply (e.g., sand and gravel) and therefore did not represent a significant effect. However, when irreversible resource commitment was handled in this fashion, the effects determined were not included in the effect summary table. This could imply that the significance of this type of effect was not considered in the final decision process. Since the irretrievable and irreversible commitment of resources is obviously linked to sustainable development, and the effect on the availability of a common resource can be used as a mechanism to connect actions, then one option that would allow greater opportunity for the consideration of this type of effect in the final decision would be to include it in the CEA.

RESULTS OF REVIEW -- Air Quality and CEA Linkages

How CEs are addressed is at least as important as what, or how many, activities are addressed. This alludes to Witmer's (1988) attributes of flexibility in: new data incorporation; temporal and spatial boundaries; and time and resource constraints. Of the 19 studies where the potential for CEs was identified, air quality CEA was often included (see Table 2.9). Seven documents included some type of quantitative emission estimation, typically linked to the project-specific air quality impact quantification, and an additional nine cases included a qualitative discussion. The seven documents with quantitative emissions estimates did not, however, provide a summary table or sample calculations. Rather, the results were discussed within the text of the CEs discussion, implying that the

Table 2.9: Summary Statistics of Treatment of Air Quality-Related Cumulative Effects

Action Type	Emissions Estimates		Qualitative Discussion		Air Quality CEs Not Addressed or Determined to be Insignificant without Discussion or Analysis	
	EA	EIS	EA	EIS	EA	EIS
AFB Disposal and Reuse	N/A	4	N/A	4	N/A	2
Mission Realignment/Beddown	2	1	4	0	0	0
AFB Closure	N/A	0	N/A	0	N/A	1
Facility Construction and Demolition	0	N/A	1	N/A	0	N/A
Totals (of 19 documents identifying potential CEs)	**2**	**5**	**5**	**4**	**0**	**3**

calculations were accomplished. Greater credibility would be given to the analysis if calculation summaries and examples had been included.

Thirteen documents (1) addressed CEs, (2) included a definition of how the term "cumulative effect" was to be applied within the document, and (3) identified potential CEs resulting from the contemplated action (see Table 2.10). If meeting these three criteria is considered to be a fundamentally important starting point for consideration of adequacy in CEA, then what, if any, common trends can be found in the air quality-related CEA of the reviewed documents?

All 13 of the documents meeting the above listed three criteria included air quality effects consideration on both local and regional spatial scales. All 13 used regional monitoring data to determine the regional ambient pollutant concentration levels without the contemplated action. All 13 also contained project-specific quantitative emissions estimations, predictions, and analysis of the air quality impacts anticipated from the proposed action and its alternatives. Ten of the EISs and one EA included some type of project-specific air quality modeling results. Finally, 11 cases provided some type of guideline for the determination of the significance of the air quality impacts.

Additionally, the seven documents that included quantitative air quality CEA all met the three criteria. This suggests that quantification of air quality CEs is also important for adequate CEA. Ten of the documents meeting the three criteria were base disposal and reuse EISs; and the remaining three were mission realignment/beddown EAs.

Table 2.10: EISs and EAs (separated by type of action) that Met Three Cumulative Effects Assessment Criteria[1]

Action Type	No. of EISs Meeting Criteria	No. of EAs Meeting Criteria
AFB Disposal and Reuse	10/14	N/A
Mission Realignment/Beddown	0/1	3/7
AFB Closure	0/4	N/A
Facility Construction and Demolition	N/A	0/1
Totals	**10/19**	**3/8**

[1]The CEA Criteria referred to are: (1) CEs are in some way addressed in the document; (2) a working definition of CE is included in the document; and (3) the potential for CEs relative to the environmental media or resources directly impacted by the action is identified.

Some of the documents reviewed included detailed, comprehensive air quality effects analysis without addressing or identifying the potential for CEs. However, a quantitative air quality analysis, including background pollutant concentrations, was found in all of the documents where a valuable discussion of the CEs on air quality was presented. This provides additional support to the conjecture that comprehensive, quantitative air quality effects analyses at the project level will facilitate a more adequate approach for addressing CEs on air quality.

RESULTS OF REVIEW -- Comparison to Related Study

The CEA consideration study conducted by McCold and Holman (1995) analyzed 89 EAs prepared by 13 separate federal agencies to ascertain the degree to which the assessment of CEs met the requirements established by CEQ. The study of 27 USAF NEPA documents presented herein addressed similar issues. Although the McCold and Holman study did not include any USAF EAs, some comparisons can be made between the two studies which serve to reinforce the results of each. Table 2.11 presents some summary statistics relative to the two studies.

Due to the differences in the time frame, sample size and type, and specific focus for each of the studies, it is not possible to draw absolute statistical comparison conclusions between the two studies. However, the general pattern shown in each study relative to the treatment of CEs within NEPA documents is similar. In both studies, of those documents that address CEs, the percentage of the documents demonstrating positive response

Table 2.11: Comparison Statistics Between this Study of USAF NEPA Documents and the Study on 89 EAs Conducted by McCold and Holman (1995).

U.S. Air Force Study 8 EAs	19 EISs	Total (27)		McCold and Holman Study (89 EAs in Study)
88%	89%	89%	Mentioned Cumulative Effects	39%
88%	63%	70%	Identified Potential for Cumulative Effects	30%
75%	58%	63%	Discussed/Analyzed Cumulative Effects	25%
50%	0%	15%	Discussed/Analyzed Cumulative Effects for All Affected Resources	3%
Document Timeframe July 1989 - March 1996				Document Timeframe January 1992 - June 1992

decreases as the level of investigation into the detail of the CEA increases. In other words, in both studies, fewer documents discuss or analyze the CEs relative to every affected resource than mention or recognize the potential for CEs.

The inconsistencies in the approach taken to CEA, indicative of the need for improved methods, is also reflected in these statistics. Throughout this analysis, base disposal and reuse EISs were consistently found to be the most comprehensive analytical documents. However, this statistical summary shows that no EIS included a complete analytical discussion of CEs. Additionally, two of the EAs shown to include analytical discussion of CEs for all affected resources did not meet all of the CEA criteria presented in Table 2.10. They did not include a working definition of CEs.

LESSONS LEARNED AND PROPOSED METHOD

The results of this evaluation of USAF NEPA documents highlight opportunities for the advancement of the assessment of air quality and cumulative effects within the environmental impact assessment (EIA) process. The following lessons learned are delineated with the intent that they could be included in future impact studies of federal agencies and/or private sector projects involving air quality concerns. For project-specific air quality effects assessment:

(1) background (without project) ambient air pollutant concentrations can be used as a baseline for determining the relative change in quality resulting from the proposed activity as well as serve as a representation of past actions for a cumulative analysis;

(2) percent change in emissions can provide a contextual framework for assessing the significance of air quality effects where there is little concern over reaching or exceeding a stated standard;

(3) quantification of air quality effects removes some of the subjectivity in significance determination when combined with significance guidelines;

(4) documentation of the uncertainty of the quantitative analysis methods reduces the likelihood that resultant predictions are viewed as "absolute fact" by decision makers;

(5) including specific guidelines for the determination and ranking of the significance of air quality effects clarifies significance for interpretation and incorporation into decision making; and,

(6) the interpretation and incorporation of the significance of an air quality effect into the overall decision making process can be achieved through mechanisms such as an overall significance chart or table, however, care must be taken in determining the scaling and weightings used to combine the significance of varying media effects within the context of the activity type, size, and location.

For cumulative effects assessment:

(1) ensure that the federal agency EIA professionals have a common understanding of the definition of the term "cumulative effect" and how it is to be applied in the analysis (the CEQ definition presented in 40 CFR 1508.7 is recommended);

(2) ensure that a concerted effort is made to include and document past, present, and reasonably foreseeable future actions both internal and external to the subject agency in the CEA;

(3) address, at least in a scoping exercise, the potential for CEs relative to every environmental medium or resource included in the project specific impact assessment;

(4) provide, if possible, quantified predictions of the CEs in order to, as with air quality, remove subjectivity from the significance determinations;

(5) include a significance determination for CEs, ensure that the guidelines for significance determinations are clearly stated, and present rationale for how the significance of the CEs are included in the overall decision process; and,

(6) include the discussion of irretrievable and irreversible commitment of resources within the CE portion of the analysis to ensure that the significance of those resource commitments is included in the decision making process.

The accomplishments and failings discovered through this analysis of 27 USAF NEPA documents can be utilized as the basis for the development of a method for conducting a "cumulative air quality effects assessment" (CAQEA). Table 2.12 presents a proposed series of eight steps for application in CAQEA. The CEA process can be accomplished either as an integral part of the EIA process applied to a specific project; or, it can be accomplished as a separate study for a general area and timeframe and incorporated by reference into individual project assessments. Regardless of which approach is taken, the eight steps presented in Table 2.12 are applicable.

The requirements presented in the eight steps proposed in Table 2.12 can be related directly to Canter's (1996) six steps shown previously in Table 2.1. A summary table illustrating the step linkages is presented in Table 2.13. For example, in Steps 2, 3 and 5 of the CAQEA method, activities are determined, within a set of time and space boundaries, that are to be analyzed for air quality effects. Also, the type and quantity of emitted pollutants is estimated. These steps are similar to Step 1 in Canter's model where the specific activities or phases of the proposed action likely to affect air quality are identified. Once identified, pollutant type and quantity estimates are developed for the proposed action. Step 6 of the CAQEA proposal and Step 4 of Canter's model are both focused on technical predictions, with possible differences only in the predictive methods employed and the level of detail of the analysis. Finally, Steps 7 and 8 of the CAQEA proposal are specifically intended to be incorporated within the requirements Canter presents in Steps 5 and 6, respectively.

Table 2.12: Proposed Steps for Cumulative Air Quality Effects Assessment (CAQEA)

Step	No. of Documents Observed[a]	Comments
1. Select definition of CE to be applied to the analysis.	18	CEQ definition is recommended.
2. Determine spatial and temporal boundaries.	27	Consider physical airshed and political regions (spatial) and forecasting capability limitations (temporal).
3. Determine past, present, and reasonably foreseeable future actions to be included in the analysis.	18	18 document addressed specific projects identified for inclusion in CEA.
4. Determine background ambient air pollutant concentrations and obtain applicable standards.	21	Regional air quality monitoring station data is recommended.
5. Develop quantitative and qualitative emission data estimates for the actions determined in Step 3.	16	Not all 16 documents included both quantitative and qualitative analysis.
6. Determine quantitative and qualitative change to background air quality (determined in Step 4) resulting from evaluated actions.	16	Not all 16 documents included both quantitative and qualitative analysis. Emissions inventories and quantitative air quality modeling can be useful.
7. Evaluate the CE significance in context with the air quality impacts of the action originally generating the NEPA requirement and incorporate that significance into the assessment.	0	Necessary to properly determine impact significance.
8. Include mitigation opportunities for CEs when discussing specific action impact mitigation.	0	Additional mitigation opportunities/options are available when other activities are considered.

[a] Out of 27 documents in the study group

Table 2.13: Comparison between Canter's 6-Step Project-Specific Model and the Proposed 8-Steps for CAQEA

1. Select definition of CE to be applied to the analysis.	
2. Determine spatial and temporal boundaries.	**Step 1:** Identification of Air Quality Impacts of Proposed Project
3. Determine past, present, and reasonably foreseeable future actions to be included in the analysis.	**Step 2:** Description of Existing Air Environment Conditions
4. Determine background ambient air pollutant concentrations and obtain applicable standards.	**Step 3:** Procurement of Relevant Air Quality Standards and/or Guidelines
5. Develop quantitative and qualitative emission data estimates for the actions determined in step 3.	**Step 4:** Impact Prediction (technical)
6. Determine quantitative and qualitative change to background air quality (determined in step 4) resulting from evaluated actions.	**Step 5:** Assessment of Impact Significance
7. Evaluate the CE significance in context with the air quality impacts of the action originally generating the NEPA requirement and incorporate that significance into the assessment.	**Step 6:** Identification and Incorporation of Mitigation Measures
8. Include mitigation opportunities for CEs when discussing specific action impact mitigation.	

In summary, this study focused on the recent past performance of the USAF in the preparation of air quality-related portions of NEPA documents. Specifically, this evaluation targeted the efforts in project-specific air quality effects and how air quality is addressed in CEA. The intent of the evaluation was to identify valuable methods currently used by EIA professionals as well as areas where improvement opportunities exist. The lessons learned were obtained by targeting the assessment procedures of the USAF. However, they can be used by other government agencies and the private sector, both nationally and internationally, in the continuing effort to make the EIA process more efficient and effective.

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Chapter 3

Addressing Future Actions in Cumulative Effects Assessment

ABSTRACT

Consideration of cumulative effects within the environmental impact assessment (EIA) process in the United States involves an analysis of the proposed action in view of past, present, and reasonably foreseeable future actions (RFFAs) in the related environs. Information gathering and analyses related to RFFAs may be the most difficult aspects of addressing cumulative effects. In fact, a fundamental question may be -- when does a contemplated action become "reasonably foreseeable?" In EIA practice in the United States, over 40 court cases have involved cumulative effects, and many of them have hinged on RFFAs. This paper summarizes the lessons learned, including contradictions, and inconsistencies, from the relevant court cases. Such lessons can be viewed as forming the basis for systematic criteria used to determine when any possible future action becomes a RFFA, thus necessitating its inclusion in cumulative effects considerations. An 8-step Conservative Determination Method is thus proposed for delineating RFFAs for inclusion in studies which address cumulative effects. Although the Method was based on principles and lessons derived from U.S. court cases, it can be used internationally to help delineate RFFAs.

BACKGROUND

Cumulative effects analysis is an important, yet often overlooked, aspect of the environmental impact assessment (EIA) process. In the United States, the National Environmental Policy Act (NEPA) requires, in spirit, that cumulative effects be addressed in

stating a general policy that requires the protection, restoration, and maintenance of environmental quality for the use and enjoyment of present and future generations through the use of all practicable means that are consistent with other aspects of national policy (Kamaras, 1993). The Council on Environmental Quality (CEQ) states that cumulative impacts (effects) result from "the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (CEQ, 1996). Adequate consideration of cumulative effects within the EIA process in the United States must, therefore, involve an analysis of the proposed action in view of past, present, and reasonably foreseeable future actions (RFFAs). One key difficulty in this analysis is the determination of what activities should be considered as RFFAs. For over two decades, the answer to the question -- when does a contemplated action become "reasonably foreseeable?" -- has been argued in the United States courts. In fact, over 40 court cases have involved cumulative effects, and many of them hinged on the determination of RFFAs.

One goal of the EIA process is to provide substantive and complete environmental information for decision making. If the resultant environmental impact statement (EIS) or other environmental planning document (a preliminary study is called an "environmental assessment") includes such significant informational or analytical gaps as to provide project opponents an opportunity to challenge the adequacy of the environmental study in a court of law, then possibly, the assessment process needs to be revised. "In the last few years, the courts have been increasingly willing to scrutinize the analysis of the effects of the agency action, combined with other relevant actions, and reject NEPA documents because of

inadequate cumulative impact analyses" (Herson and Bogdan, 1991). The lack of clear, concise definitions and assessment procedures has resulted in decision making that appears to conflict with the spirit and purpose of NEPA. Clear direction is needed as to what cumulative effects are and when they must be addressed in order for the fundamental objectives of NEPA and other environmental planning and protection statutes to be achieved (Kamaras, 1993). A review of the court cases addressing the issue of RFFA determination provides insight into the nature of the problem and offers the opportunity to develop improved procedures to avoid future litigation.

This paper is presented in three main sections: an analysis of U.S. court cases, a review of some existing methods for addressing RFFAs, and the presentation of a proposed method for determining RFFAs. The court case analysis addresses key issues such as: the controversy between formal and informal proposals, connection between actions, speculation, planning relationships, and adequacy determinations. Overlaps can be found throughout the analysis between cases and issues. A single case will occasionally address multiple issues and, as finer points are revealed, the distinctions between the issues themselves become blurred. The methods review includes discussions on forecasting and an exclusion test developed within the court system. Finally, the proposed method incorporates the lessons learned in order to enhance environmental decision making.

ANALYSIS OF COURT CASES

Formal vs. Informal Proposals

A well known NEPA court case is *Kleppe v. Sierra Club* (1976). In this case, the Supreme Court reviewed the U.S. Department of Interior's past and contemplated actions

with respect to coal development. The court found that, in order for activities to require a "programmatic EIS," or one that encompasses the cumulative effects of several related past, present, and future proposed actions, it was necessary for those future actions to be formally proposed. In other words, if the future plans of the agency were not formalized into some type of program proposal, or regional development plan, then they were not sufficiently foreseeable to trigger cumulative effects assessment (CEA) requirements (Herson and Bogdan, 1991). This decision established a precedent that has been used to argue cases, successfully, for over two decades. For example, in *Hart & Miller Islands Area Environmental Group, Inc. v. Corps of Engineers of United States Army* (1980), the court held that the Corps did not need to consider the cumulative effects of dredging an access channel and deepening a harbor related to the proposal for a diked spoil disposal facility in Chesapeake Bay because the actual dredging and deepening projects were not yet formal proposals. The court cited *Kleppe v. Sierra Club,* thus indicating that an agency could approve one project covered by an impact statement and reserve assessment of related projects until later when they were formally proposed (Mandelker, 1991). The court stated that actions that are merely contemplated did not have to be addressed (Hart & Miller Islands, 1980).

The contemplated action interpretation of reasonably foreseeable was used successfully again in 1990 and later in 1994. The 1990 case of *National Wildlife Federation v. Federal Energy Regulatory Commission*, involved a two phase proposal to build a dam and increase available water supply. The Federal Energy Regulatory Commission prepared an EIS to address Phase I of the project but did not include an assessment of the impacts from Phase II even though it would significantly increase the

water supply available from the reservoir. The court found that, since the second phase had not yet been formally proposed, it would not inevitably follow from the first phase and therefore was only hypothetical and did not require analysis. Only the particular proposal at issue in the EIS and other pending or recently approved proposals needed to be addressed (NWF v. FERC, 1990).

In 1994, the United States Air Force neglected to include the cumulative effects resulting from a related, formally proposed training range when developing the EIS for a proposed composite wing project at Mountain Home Air Force Base in Idaho. It was determined that, since the training range was connected to the composite wing project and EIS preparation began for the range as soon as the record of decision (ROD) for the composite wing was issued, the training range proposal was not speculative and its impacts should have been addressed in the original EIS (*Shoshone-Paiute Tribe v. U.S.,* 1994).

While these four cases, ranging from 1975 to 1994, support a narrow view of what is "reasonably foreseeable," other court actions, throughout the same time period, demonstrate the emergence of a broader definition of a "proposal." For example, in *National Resources Defense Council v. Callaway* (1975), the court made a direct ruling on the proper scope of cumulative effects analysis with respect to what projects or project proposals were reasonably foreseeable. The court determined that an agency was required to consider and include the cumulative impacts (effects) of the proposed project and any related projects that, although not approved yet, had reached a stage beyond speculation (Herson and Bogdan, 1991). Requiring the consideration of informal proposals contradicts the "formal proposal only" decision in *Kleppe*.

Ten years later, in *Fritiofson v. Alexander* (1985), the court relied on the CEQ definition of the term "significantly" (40 CFR 1508.27), as related to NEPA, to direct a federal agency to conduct a cumulative effects assessment of a project which was not formally proposed (Herson and Bogdan, 1991). In this case, the Corps of Engineers had determined that it was not necessary to prepare an EIS for the approval of a permit authorizing a housing developer to construct a canal system for a housing project on a Galveston Bay island in Texas. The court determined that the *Kleppe* ruling was not appropriate where an agency is "assessing the environmental significance of an action to determine whether an impact statement should be prepared" (Herson and Bogdan, 1991). The court determined that the CEQ regulations imply that the impact of other actions, in cases where those other actions are predicated on the original action, must be considered with the proposed action, even though they have not yet reached the proposal stage (Herson and Bogdan, 1991).

Conversely, the court determined in *Ringsred v. City of Duluth* (1987) that CEA was not even required for environmental assessments (EAs) since it would place a burden on the agency's screening process equal to that required for an EIS (Kreske, 1996).

While *National Resources Defense Council v. Callaway* set a precedent for inclusion of informal proposals as RFFAs, this case also addressed the consideration of non-Federal as well as Federal actions. An included subsequent informal, but reasonably foreseeable, proposal for housing construction was a private, not Federal, action. The U.S. Court of Appeals for the Fifth Circuit found that CEQ regulations "clearly mandate consideration of the impacts from actions that are not yet proposals and from actions - past,

present, or future - that are not themselves subject to the requirements of NEPA" (Council on Environmental Quality, 1985).

The expanded RFFA view that included informal proposals did not, however, totally replace the *Kleppe*-based view. Courts still used *Kleppe* in the mid-1990s. The viewpoint requiring a formal proposition prior to consideration as reasonably foreseeable was presented, most adamantly, in *Clairton Sportsmen's Club v. Pennsylvania Turnpike Commission* (1995) where the court stated that it "clings firmly to the notion that a proposal requiring an EIS is a creature actually pending before a federal agency. Thus if a project is only 'contemplated' or 'less imminent,' it does not merit inclusion in an EIS" (Clairton, 1995). Apparently, the courts had not yet resolved the contradictory opinions regarding the necessary degree of formality (as summarized in Table 3.1). Expansion to the view of reasonably foreseeable brings with it an additional, subjective, determination problem. That problem is associated with the degree to which an informally proposed, and possibly connected, action is probable.

Reasonably Foreseeable or Speculative

The courts have had opportunity to decide what constitutes an action that is a probable future event and one that is merely speculative (see Tables 3.1 and 3.2). This decision separates informal proposals into two categories, reasonably foreseeable and speculative, based on the probability of occurrence. In *Cheney v. City of Mountainlake Terrace* (1976), the court was asked to determine the requirement for CEA on the possibility of cumulative effects resulting from an arterial road construction project in the state of Washington. The court determined that the road was being built only to serve existing

Table 3.1: Summary of Court Cases Related to Formal v. Informal Proposals

Outcome	Case
Only formal proposals are required to be considered as RFFAs	Kleppe v. Sierra Club (1976) Hart & Miller Islands Area Environmental Group, Inc. v. Corps of Engineers of United States Army (1980) National Wildlife Federation v. Federal Energy Regulatory Commission (1990) Shoshone-Paiute Tribe v. U.S. (1994) Clairton Sportsmen's Club v. Pennsylvania Turnpike Commission (1995)
Informal proposals beyond the point of speculation are required to be considered as RFFAs	National Resources Defense Council v. Callaway (1975) Fritiofson v. Alexander (1985) Thomas v. Peterson (1985)
Remote or speculative informal proposals are not required to be considered as RFFAs (see Note 1)	Cheney v. City of Mountainlake Terrace (1976) Lake County Energy Council v. Lake County (1977) Headwaters Inc. v. Bureau of Land Management (1990)

Note 1: See Table 3.2 for related outcomes.

Table 3.2: Summary of Court Cases Related to Reasonably Foreseeable v. Speculative Actions (see Note 1)

Outcome	Case
Speculative effects are not required to be included after scoping process determines significant/speculative issues	Marin Municipal Water Dist. v. KG Land California Corp. (1991)
Future actions that (1) are a direct consequence of the current action and (2) where consideration could alter the nature of the project or its effects are to be considered as RFFAs	Laurel Heights Imp. Ass'n of San Francisco v. Regents of University of California (1988); see Glad (1991)
Reasonable amount of forecasting of future activities is required	San Francisco Ecology Center v. City and County of San Francisco (1975)
Future actions directly tied to an overall goal are to be considered as RFFAs	Blue Ocean Preservation Society v. Watkins (1991)

Note 1: See also the last listed outcome in Table 3.1.

traffic needs in the area. It was not being constructed as part of an effort to encourage further economic development in the area. Since there were no future development plans being contemplated by the agency which included the construction of the new road, the "future use of the private parcel is too remote and speculative to call for present evaluation of its future development" (Cheney, 1976). The court used the State Environmental Policy Act (SEPA) for Washington to support its decision, citing that SEPA does not require every remote and speculative consequence of an agency action to be addressed in an EIS.

In 1977, during *Lake County Energy Council v. Lake County*, the First District Court in California ruled, "where future development is unspecified and uncertain, no purpose can be served by requiring environmental impact reports to engage in sheer speculation as to future environmental consequences" (Lake County, 1977). The court determined that approval of exploratory drilling for the assessment of potential did not commit the council to approval of general commercial development of geothermal resources. The scope of the larger, commercial project was unknown until the smaller, exploratory project was completed and the court felt it was impossible to address the cumulative effects of the second, larger project without clear a definition of its scope (Lake County, 1977).

In a case similar to *Cheney v. City of Mountainlake Terrace*, the Ninth Circuit upheld a Bureau of Land Management (BLM) decision not to supplement an EIS. In the reference case, *Headwaters Inc. v. Bureau of Land Management* (1990), the court found that when the BLM decided to sell its Wilcox Peak area, it needed only to prepare an EIS relating to the construction of the access road needed to enter the area in order to present it for sale. The court found no evidence that any further activities, such as logging, were

contemplated by the BLM for the Wilcox Peak area (Headwaters, 1990). Although the court agreed that it was possible for the road to be used for future logging activities, it was also possible that the road would never be used for any development activities. The future use of the road was considered to be speculation, and, therefore, did not require evaluation of hypothetical cumulative effects (Herson and Bogdan, 1991). The difficulty, then, is to determine the difference between when a future activity is to be considered as a reasonably foreseeable, albeit informal, proposal and when it is sheer speculation.

The court in *Marin Municipal Water Dist. v. KG Land California Corp* (1991) reached the conclusion that the future possibilities in question were not more definitive than sheer speculation and therefore, CEA of the possible future effects was not required. In this case, a draft EIR (environmental impact report -- the term used for an EIS under the California state law) was prepared on a moratorium to restrict new water allocations until a new water resources management plan could be completed. At this point, of the 35,000 acre-feet annual supply, only 18 acre-feet was unallocated. The draft EIR addressed issues such as the possible impact on housing stock, housing affordability, employment and public finances. The opponents of the moratorium argued that the draft EIR was insufficient because it failed to address: the ability of cities to meet their regional fair share of housing; regional job and housing imbalances; regional growth and development issues; and the generation of fees for public services. The court held that analyzing "whether a project may have a significant environmental effect necessarily involves some degree of forecasting" but also the EIR should not engage in sheer speculation of future effects (Marin Municipal, 1991). Not only are speculative actions not required to be addressed in a CEA, but

speculative significance determinations, relative to scoping of the issues addressed, are also not required.

The court, in *Laurel Heights Imp. Ass'n of San Francisco v. Regents of University of California* (1988), took on the challenge of the delineation between speculation and RFFAs. The court found that the EIR prepared for moving a university biomedical science unit into a portion of a new building was inadequate in that it did not discuss the future use of the entire new facility. To make this determination, the court established a test to decide when future actions related to a proposed project should be analyzed in conjunction with the original proposal (Glad, 1991). The state supreme court stated that the decision of future action inclusion in the analysis involved a balancing of whether the future actions were too speculative versus the possibility of ignoring some important environmental issue in decision making if the environmental analysis of the future proposal is conducted too late. The court test required the inclusion of the future proposals in the environmental analysis if the future activity (1) was a reasonably foreseeable consequence of the original, or initial, project; and (2) it will be significant in that it will likely alter the nature or scope of the original project or its environmental effects (Glad, 1991).

The court applied this test to the *Laurel Heights* case and concluded that even though there were no formally approved plans as to the future use of the remainder of the facility, since public and private disclosures were made by university officials as to the general types of future activities that were likely to occur, those possible activities were beyond the point of mere speculation and could be considered as RFFAs. The court also noted that the EIA process always involves some degree of forecasting and it is the

responsibility of the public agency to disclose all pertinent information (Glad, 1991). Thus the test applied by the court seems to indicate that, in order for an action to be required to be included in a CEA, it must, at a minimum, be a connected informal action of some environmental significance.

Connected Actions

The courts have also explored other mechanisms to clarify the requirement to "forecast" future activities (see Table 3.3). In *San Francisco Ecology Center v. City and County of San Francisco* (1975), the court stated that agencies are encouraged to make reasonable forecasts in the preparation of environmental impact analysis documents and if, later, information becomes available that invalidates or alters those projections, that information should be brought to the attention of the decision makers (SF Ecology Center, 1975). In *Thomas v. Peterson* (1985), the court related the idea of a reasonably foreseeable informal proposal to "connected actions." The court held that the EIS prepared by the U.S. Forest Service was insufficient because CEQ regulations required cumulative impact (effects) analysis of "connected actions." It was determined that an impact statement was required for both a proposed road through a forested area and the future logging activities conducted using that road as an access route. Since the cutting and selling of timber could not occur without the road, and since the road would not be constructed if it were not for the contemplation of timber sales, the two projects were connected within the regulatory definition of connectedness (Thomas v. Peterson, 1985).

The relationship of connected actions was used again in *Save the Yaak Committee v. Block* (1988). Relying heavily on the decisions made in *Thomas v. Peterson*, the Ninth Circuit Court "found the EA inadequate, because it failed to consider timber harvest and

Table 3.3: Summary of Court Cases Related to Connectedness of Actions

Outcome	Case
Lack of independent utility or demonstration as a logical part in a chain requires subsequent related actions to be evaluated together	Thomas v. Peterson (1985) Scientists Inst. for Public Information v. Atomic Energy Commission (1973) Save the Yaak Committee v. Block (1988) Town of Huntington v. Marsh (1988)
Actions having independent utility are not required to be evaluated together	Lange v. Brinegar (1980) SEAPC v. Cammack II Orchards (1987) Hudson River Sloop Clearwater Inc. v. Navy Department (1988)
Geographic connections require actions to be evaluated together	Scientists Inst. for Public Information v. Atomic Energy Commission (1973) Onondaga Landfill Systems Inc. v. Flacke (1981); see Kamaras (1993) Northwest Indian Cemetery Protective Ass'n v. Peterson (1985)
Geographic connections are not sufficient to require actions to be evaluated together	Allison v. Department of Transportation (1990)
Other future actions within an agency undergoing the same level of review must be evaluated with the proposal	San Franciscans for Reasonable Growth v. City of San Francisco (1984); see Kamaras (1993)
Common natural resource threat or commitment connections or environmental effect connections require actions to be evaluated together	Northwest Indian Cemetery Protective Ass'n v. Peterson (1985) Citizens to Preserve the Ojai v. County of Ventura (1985) Connor v. Burford (1988) Kings County Farm Bureau v. City of Hanford (1990)

secondary roadway construction enabled by the road as 'connected actions' that would cause cumulative effects" (Herson and Bogdan, 1991). Specific "connections" include: proposal intent, geographic connections, resource connections, and planning relationships.

Proposal Intent and Geographic Connections

Where a reasonably foreseeable action is one that does not have to be formally proposed, yet is more concrete in its probability than to be considered speculative, then, according to the court in *Blue Ocean Preservation Society v. Watkins* (1991), the proper delineation of reasonably foreseeable lies within the context of how the term "proposal" is defined. The court addressed the issue of whether or not the fourth phase of a geothermal project in Hawaii was reasonably foreseeable. The court determined that the agency had a clear goal of implementing the third phase and an ultimate goal of implementing Phase IV (Blue Ocean, 1991). The court cited the following in support of its determination that since the agency had a defined goal, the fourth phase of the project was reasonably foreseeable:

> "Proposal" exists at that stage in development of an action when an agency subject to the Act has a goal and is actively preparing to make a decision on one or more alternative means of accomplishing that goal and the effects can be meaningfully evaluated...A proposal may exist in fact as well as by agency declaration that one exists (CEQ, 1996).

While it is not difficult to see relationships between multiple projects or proposals of one agency in relation to one objective or goal, some court cases revealed other linkages or lack thereof between projects that influenced decisions on CEA requirements. As early as 1973, the courts recognized that geographic relationships could link reasonably foreseeable events in ways that required those events to be evaluated together. For example, in *Scientists Inst. for Public Information v. Atomic Energy Commission* (1973), the court

recognized that reasonable forecasting was implicit in the NEPA process and agencies must not be permitted to dismiss the discussion of future effects as speculation (Scientists Inst., 1973). The court also stated:

> Individual actions that are related either geographically or as logical parts in a chain of contemplated actions may be more appropriately evaluated in a single program statement...[The program statement] ensures consideration of cumulative impacts that might be slighted in a case-by-case analysis (Scientists Inst., 1973).

Since the statement says "either" geographically or as logical parts in a chain, it implies that geographically connected proposals that are in no other way related should be considered in a single environmental analysis.

In contrast to the *Scientists Inst.* case, in *Lange v. Brinegar* (1980), the court held that a highway expansion project could be separated from other actions. The highway section was considered to be of substantial length between logical termini so as to have independent utility. The court determined that since it had independent utility, and the section fulfilled state and local needs, it was properly segmented from other highway expansion projects. Since no evidence was presented of any synergistic or cumulative effects that would result from the completion of this and any other highway segments along this particular interstate highway, other than an increase in traffic, CEA of this segment construction combined with other segment proposals was unnecessary (Lange v. Brinegar, 1980).

SEAPC v. Cammack II Orchards (1987) produced a similar conclusion about the reasonableness of separating actions. In this case, a developer applied for a rezoning permit for a 234 house subdivision. An EIS was prepared which reviewed only the impacts of the

subdivision establishment (e.g., site grading, street paving, and water, sewer, gas, and electric utility placement) not the impacts of the individual housing units (SEAPC v. Cammack II Orchards, 1987). The court held that the housing units were a subsequent phase of the project. Since the initial phase, the subdivision development, would be constructed regardless of whether or not the housing units were built, it was sufficiently independent of the housing construction to be considered unconnected for purposes of environmental analysis (Kamaras, 1993).

Again in 1988, the court found in *Hudson River Sloop Clearwater, Inc. v. Navy Department* that the construction of a new homeport for the U.S.S. Iowa was independent of new housing facility construction for the homeport employees. The court held that the two projects were not connected and were not required to be evaluated in a single EIS because the homeport was needed and had independent utility regardless of the housing construction (Hudson River, 1988).

In other cases, the courts have taken the viewpoint as in *Scientists Inst.* For example, in *Town of Huntington v. Marsh* (1988), when the U.S. Army Corps of Engineers proposed to issue dumping permits for dredged material disposal at a new ocean dumping site off Long Island Sound, the court determined that the EIS was inadequate because it concluded that the type, quantity, and cumulative effects of the dumped material would be evaluated on a case-by-case basis during permit application review (Huntington, 1988). The court held that the project was improperly segmented because the designation of the dump site had no independent utility apart from its planned usage of receiving waste (Herson and Bogdan, 1991).

In some cases, the courts have expanded on what can be considered to be connected. In *Onondaga Landfill Systems, Inc. v. Flacke* (1981) in New York, it was decided, because the term "action" was defined so as to include future phases, that future aspects of the original action must be addressed as early as possible (Kamaras, 1993). The lessee-operator of a gravel mine was required to assess the future impacts of site reclamation by the property owner who had intentions of developing the area into a residential subdivision (Kamaras, 1993). These actions were required to be combined for environmental analysis due to their geographic link, however, it is important to note that they were not actions proposed by the same individual. Thus the concept of connected actions was expanded beyond those proposed by a single agency.

Finally, in *San Franciscans for Reasonable Growth v. City of San Francisco* (1984), the court held that a relationship, or connection, exists between projects such that, when project proposals within an agency are undergoing the same level of review as the subject project, the other proposals are to be considered as reasonably foreseeable (Kamaras, 1993) and connected. The court determined that the other project proposals under review were reasonably foreseeable because a significant investment of time, money, and technical planning occurs before the projects are submitted for environmental review (Kamaras, 1993).

Resource Connections

The court in *Northwest Indian Cemetery Protective Ass'n v. Peterson* (1985) determined that projects were linked, not only by geographic area, but also by threat to common natural resources. In this case, the U.S. Forest Service was required to analyze the

cumulative effects of a proposed road construction project along with a forest management plan including timber projects because they were planned for the same geographic area and represented similar threats to local aquatic resources. The Forest Service was specifically required to address cumulative sedimentation effects on water quality (Indian Cemetery Ass'n, 1985).

Another example of linkage through an environmental resource is demonstrated in *Citizens to Preserve the Ojai v. County of Ventura* (1985). This court vacated a lower court's approval of an oil refinery expansion and modification because the EIR did not include a CEA of air emissions from outer continental shelf oil facilities (OCSOF). The EIR, instead, relied on predictions made in the county air quality management plan which also excluded the outer continental shelf activity emission data. The management plan did say that the additional OCSOF emissions data would have a substantial impact (Kamaras, 1993). The linkage here, air quality, required the project proponent to address external impacts to the regionally defined resource.

In *Connor v. Burford* (1988), the court ruled that an EIS was required when the U.S. Forest Service decided to sell oil and gas exploration leases that included assessment of the development and production activities undertaken by the corporations who would purchase the leases (Connor v. Burford, 1988). This decision supports the idea of connection extending to other agency actions but was primarily made on the basis that the EIA process should be conducted prior to an irretrievable commitment of resources (Herson and Bogdan, 1991). This introduces an additional consideration of timing when considering the environmental impacts of future activities.

Planning Relationships

In some cases, RFFAs have been determined and connected to proposals undergoing NEPA analysis through the association of a planning document (see Table 3.4). For example, California Public Resources Code Section 21100(e) states: "Previously approved land use documents, including, but not limited to, general plans, specific plans, and local coastal plans, may be used in cumulative impact analysis." In *Save the Pine Bush v. City of Albany* (1987), the city separately reviewed impacts likely to result from ten pending project proposals presented by various developers for a unique ecologically sensitive area for which it had created a special zoning district (Kamaras, 1993). The court determined that the projects were related because they were part of a plan designed to add to the city's housing stock while preserving the unique character and scale of the Chinatown community (Pine Bush, 1987). The creation of a special zoning district qualified as a long range plan which, in turn, created a relationship between the projects (Kamaras, 1993). That relationship was the connectivity used to require a CEA.

The existence of a plan was also the mechanism used to define what was reasonably foreseeable in *City of Tenakee Springs v. Clough* (1990). The U.S. Forest Service had previously negotiated a 50 year timber sales contract with a paper products company. Five year operating plans were developed by the Forest Service, each supported by an EIS. A supplemental EIS was prepared to address impacts resulting from the '86 - '90 operating plan as well as deficiencies in the '81 - '86 operating plan EIS. The supplemental EIS was challenged because it did not include a comprehensive cumulative analysis of the impacts likely to result from the execution of the entire 50 year plan (Tenakee Springs, 1990). The court held that where several foreseeable similar projects in a geographic region have a

Table 3.4: Summary of Court Cases Related to Planning Relationships

Outcome	Case
Projects related through planning documents with defined goals are connected and are to be considered as RFFAs	Save the Pine Bush v. City of Albany (1987) City of Tenakee Springs v. Clough (1990)
Plans that manage actions but do not promote or stimulate the occurrence through the association of achievement of a goal are not required to be considered as connected or RFFAs	Rio Vista Farm Bureau Center v. County of Solano (1992)

cumulative impact, they should be evaluated in a single EIS prior to the time when the actions take place (Herson and Bogdan, 1991). In this case, not only did the existence of a plan connect individual actions, it acted as a mechanism to make future actions reasonably foreseeable.

It is not, however, sufficient to consider actions or proposals related solely based upon the existence of a planning document. As shown in *Rio Vista Farm Bureau Center v. County of Solano* (1992), without some causal link between the plan and the project proposals, there is no inference of connectivity or future probability. In this case the court would not allow a county hazardous waste management plan to be used as inference of a requirement to assess specifics of potential future treatment, storage, and disposal facilities. The court held that the plan was not a project development proposal but merely a management assessment and overview (Rio Vista, 1992). A plan itself does not necessarily generate the requirement for a CEA of the activities it is intended to manage. It can, however, provide the necessary linkage between projects to require CEA. Accordingly, without a plan to provide this link, even projects in close geographic proximity can fail to qualify as connected.

In *Allison v. Department of Transportation* (1990), the EIS for the new Denver airport was challenged because it did not address the cumulative effects of other projects planned for the area (Allison, 1990). The court determined that CEQ regulations did not require the inclusion of projects that were neither related to the airport nor dependent on it. Those unrelated actions were considered by the court to be unconnected (Herson and Bogdan, 1991).

In summary, it appears that in order to use a planning document as a mechanism to connect actions and qualify them as reasonably foreseeable, the document must include a stated goal. In order for attainment of that goal, the plan must promote the occurrence of the future activities it is designed to manage.

Elements of an Adequate CEA Discussion

An EIR for a large, coal fueled co-generation facility came under legal scrutiny in *Kings County Farm Bureau v. City of Hanford* (1990). This case required that the CEA address activities both on and off the proposed site regardless of what agencies were proponents of those additional actions. The court held that the project proponent was required to address on-site and off-site, or secondary, emissions concurrently in a single, cumulative analysis and that, contrary to the separation of emissions allowed under the air emission permit application process, in the EIA process, emissions from truck and train activities had to be combined with stack emissions when evaluating impact significance (Kings County, 1990). The court also provided its interpretation and review of California EIA guidelines as applicable to CEA. The elements determined necessary for an adequate discussion of cumulative impacts include: (1) either a list of past, present, and RFFAs producing related or cumulative effects, regardless of agency control; or, a summary of projections contained in an official planning document which evaluates conditions over a region or area; (2) a summary of the expected environmental effects produced by those projects; and, (3) a reasonable analysis of the cumulative effects of the relevant projects (Kings County, 1990).

California is one of the few states in the U.S. that has developed a specific definition of cumulative impacts and guidance on requirements for what actions to include in a CEA

(Kamaras, 1993). For example, in *Akers v. Resor* (1978), the court ruled that information, similar to that in the subsequent *Kings County* case, required to account for cumulative impacts included: a list of projects producing related or cumulative impacts, and a reasonable analysis of the combined or cumulative effects. The court went on to add that this analysis should include the projects of other agencies (Akers v. Resor, 1978).

EXISTING RFFA DETERMINATION METHODS

It should be apparent that much effort has been expended on legal determinations of RFFAs. However, the environmental planner is faced with contradictory signals from the court system as to what should be included within a CEA incorporating a RFFA. It is uncertain whether or not the future activity must be formally proposed, whether the actions of other agencies should be included and, if connected actions are required to be addressed, what is necessary to define that connection. Rather than court case-related research on CEA, most research efforts have focused on predicting the additive or synergistic impacts for specific ecosystems (Dixon and Montz, 1995). However, some methods for the determination of RFFAs have been developed by agencies, or by the courts themselves, as a result of the court experiences that have addressed the issue.

In *Considering Cumulative Effects Under the National Environmental Policy Act,* the CEQ presents a discussion on some of the issues to consider when identifying future actions. The recommendations made include a review of pertinent planning documents and "reasonable forecasting." Additionally, guidance is provided to allow for exclusion of proposals that: are outside the temporal and spatial boundaries; will not affect the resources that are the subject of the analysis, or; could be considered arbitrary (CEQ,

1997). This document does not, however, provide a pragmatic framework, or procedure, for the identification of RFFAs. Rather, it states that analysts should develop their own guidelines and that the assumptions, or basis, used to forecast future activities should be discussed in the assessment (CEQ, 1997).

The court in *No Oil, Inc. v. City of Los Angeles* (1987) approached this problem by deciding when a proposal should be excluded rather than when it should be included. The court determined that two factors should be considered when deciding whether or not to defer assessment of a future project stage until a time after the first stage assessment was complete. They are: (1) whether obtaining more detailed, and useful, information about the future stage is "meaningfully possible", and; (2) how important would the additional information be in determining whether or not to proceed with the project (No Oil, 1987). By this logic, if the future proposal is either too abstract to predict reasonably accurate environmental effects, or so insignificant as to have no real impact on the decision to proceed with the current stage, then it is not necessary to include it in the current impact study. To avoid potential misuse, it is important to note this test within the context of the case where it was presented. The case referred to deferral of consideration of the environmental effects of a pipeline until oil was discovered and a specific pipeline route was chosen (No Oil, 1987). In this case, no adverse effects were likely due to the deferral. As always, professional judgment on the part of the environmental planner and project decision makers is needed to ensure that any test is applied in the proper context.

The U.S. Forest Service has developed an approach to CEA, known as "area analysis," that addresses the problem of RFFAs. This approach involves a two-level decision process including, first, a programmatic impact analysis at the forest plan level, and

second, a site-specific impact analysis at the project level (Sample, 1991). The Forest Service addresses the boundary issues of space and time in its approach. With regard to spatial analysis, they first addressed impacts within the administrative boundaries of the Forest Service. This proved to be too limiting as it did not account for impact contributions from other agency or private individual activities. While the information from these external activities may be less accurate, or less detailed, the Forest Service approach permits its inclusion into a programmatic assessment over the geographic boundaries applicable to the impacts being addressed, e.g., watersheds. With respect to temporal bounds, the agency addresses planned activities as well as future observance of effects due to present activities. The two-level analysis method allows for updates to be incorporated as new information becomes available (Sample, 1991).

One of the most elusive aspects of the incorporation of RFFAs in CEA is the forecasting requirement addressed in *San Francisco Ecology Center v. City and County of San Francisco*. While this may appear to be an exercise in random speculation, considerable research has been conducted in the development of forecasting methods. One method, "alternative futures," includes techniques to develop possible, plausible, conceivable, and probable future activities. It emphasizes societal features that could reasonably coexist (Mitchell, et al., 1975). While this and other forecasting techniques were not specifically developed for the determination of RFFAs for CEA, the basic concepts and procedures can be adapted for that use. Reasonable effort expended on the development of possible future actions and evaluation of the relationship between these future activities and the original proposal in context with the surrounding environment, should facilitate the

development of a reasonable list of possible future activities. That list of activities can then be evaluated to determine if they can be called RFFAs.

A PROPOSED CONSERVATIVE DETERMINATION METHOD

Based on the issues addressed in the reviewed cases, and with the precondition that when the courts contradict, a conservative approach dictates that an action should be included, evaluation of future activities with respect to the following 8 steps should minimize court challenges on the basis of failure to include future actions in a CEA:

> (1) Determine reasonable temporal and spatial boundaries with respect to the availability of information, the realm of influence or control exerted by the subject agency, and the nature of the environmental impacts of the original project.
>
> (2) Within those boundaries, if the agency has additional formal proposals, approved or pending approval, relating to the accomplishment of any agency goal or objective, include them as RFFAs.
>
> (3) Conduct forecasting to determine possible, plausible, conceivable, and probable future activities both internal and external to the subject agency that fall within the temporal and spatial boundaries established in Step 1. This is not intended to encompass every speculative possibility. Evidence to support the likelihood of each forecasted activity should be included in the analysis. For example, a forecasted housing development informal proposal could be supported by population growth projections and existing dwelling unit occupancy statistics that demonstrate the need for the development. Other supporting evidence could be provided through a discussion of any linkages to formal proposals identified in Step 2.
>
> (4) Evaluate the list from Step 3 to determine possible connectedness to the original proposal. Consider: (a) geographic relationships; (b) common resources or environmental media impacted; and (c) causal links or catalytic effects, between the original and forecasted activities. If connections can be determined, consider those activities as RFFAs.
>
> (5) Again evaluating the list of proposals from Step 3, determine if "significant amounts" of effort, resources, time, and/or money have been invested into the future activities. If so, consider the activities as RFFAs.

(6) Within the area of concern, determine the existence of any planning documents, such as city or regional development plans, historic preservation plans, district plans, or environmental use plans, that relate future activities and the original proposal through a common goal or objective. If such relationships can be determined, consider the related future activities as RFFAs.

(7) Evaluate the significance of each activity thus far categorized as reasonably foreseeable. Include consideration of: (a) whether or not obtaining useful information, or relevant prediction models, related to the environmental impacts of the activity is possible at this point in time; and (b) whether or not the information obtained will have any impact on the original project alternative evaluation and selection. This determination is not intended to evaluate the significance of the project effects on the environment. It is a scoping exercise to ensure that the RFFA list is limited to only those activities with measurable effects on the resource or media of concern relevant to the scale of the analysis. If RFFAs are determined to be "insignificant" or impossible to evaluate at this time, exclude them from the list. The remaining RFFAs should be included in the CEA for the original project.

(8) Document the evaluation of RFFAs and include that documentation in the final impact study report.

The order of the steps is intended to demonstrate a logical flow for the decision making process. This does not mean , for example, that Step 1 must be completed prior to exerting effort toward Step 2. Nor is it intended to imply that, once completed, the results of a step can not be revised. The importance resides in the inclusion of each issue for RFFA determination regardless of the order of step completion or number of iterations.

Table 3.5 summarizes how the issues addressed in the court cases relate to and support each of the eight steps. Following these eight steps through the decision process illustrated in Figure 3.1 will ensure that most, if not all, relevant projects are included. It will demonstrate to the decision makers, regulators, and if necessary, the courts, that a concerted effort was made to comply with the spirit of the legislation and provide the pertinent information needed to make responsible decisions with respect to the protection of the environment.

Table 3.5: Legal Issue Linkages to 8-Step Method

Issue Addressed	Table	Step Affected	Comments
Only formal proposals are required to be considered as RFFAs	3.1	2	
Informal proposals beyond speculation are to be considered as RFFAs	3.1	3	
Remote or speculative informal proposals are not required to be considered as RFFAs	3.1	3,7	
Speculative effects are not required to be included after scoping process determines significant/speculative issues	3.2	7	
Future actions that (1) are a direct consequence of the current action and (2) where consideration could alter the nature of the project or its effects are to be considered as RFFAs	3.2	3,4,7	
Reasonable amount of forecasting is required	3.2	3	
Future actions directly tied to an overall goal are RFFAs	3.2	6	
Lack of independent utility or demonstration as a logical part in a chain requires related actions to be evaluated together	3.3	4	
Actions having independent utility are not required to be evaluated together	3.3	N/A	Does not support conservative approach
Geographic connections require actions to be evaluated together	3.3	1,3	
Geographic connections do not to require actions to be evaluated together	3.3	N/A	Does not support conservative approach
Other future actions within an agency undergoing the same level of review must be evaluated with the proposal	3.3	5	
Common natural resource threat or commitment or environmental effect connections require actions to be evaluated together	3.3	4	
Planning document related actions supporting defined goals are connected and are to be considered as RFFAs	3.4	6	
Plans that manage actions but do not promote their occurrence through the association of a goal are not required to be considered as connected or RFFAs	3.4	6	

Note 1: Step 7 is also influenced by discussions on adequate CEA (*Kings County Farm Bureau v. City of Hanford*, 1990 and *Akers v. Resor*, 1978) and exclusion testing (*No Oil, Inc. v. City of Los Angeles*, 1987).

Note 2: Step 8 was not developed from court case review, however, proper documentation is central to the EIA and CEA processes.

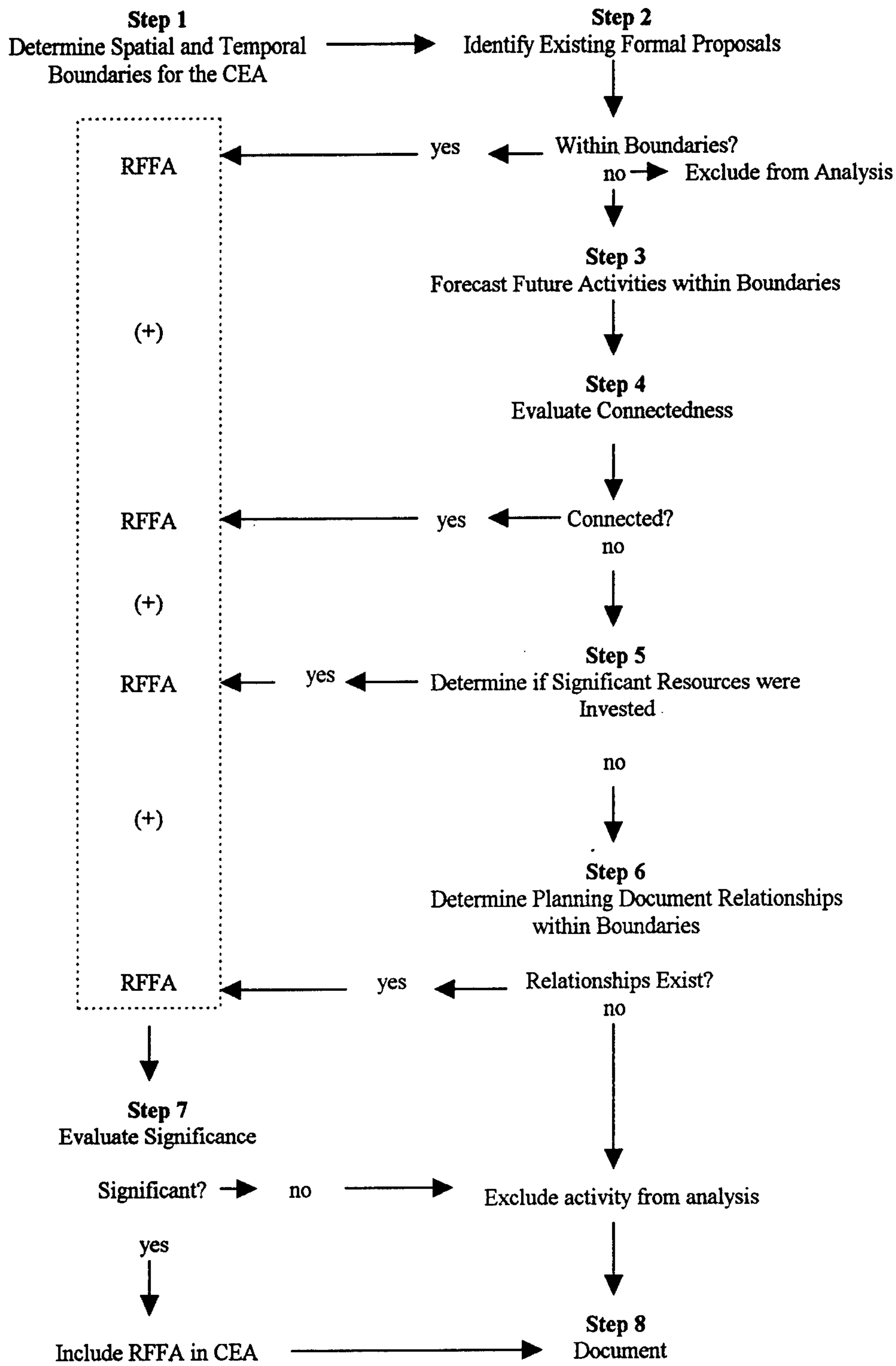

Figure 3.1: 8-Step Method Decision Flowchart

CONCLUSIONS

As stated by the court in *Coalition for Canyon Preservation v. Bowers* (1980), "subjective good faith is not the test for determining adequacy of an environmental impact statement; [the] test is an objective one" (Canyon, 1980). The proposed 8-Step Conservative Determination Method described above, while not entirely devoid of the subjective, attempts to organize the RFFA determination process into a methodical, defensible procedure. Using this Method, agencies can show why an action is, or is not, included in a CEA. "Agencies will be more likely to withstand cumulative impact challenges if alleged connected actions are not related closely, if the projects are not segmented, and if there is evidence specifically rejecting connected actions and evidence of good faith attempts to comply with NEPA" (Herson and Bogdan, 1991). Since there are no penalty provisions associated with NEPA, if an agency does not voluntarily make the good faith attempt, the only recourse left to concerned groups and individuals is to convince the court that the analysis is inadequate, therefore delaying, or possibly canceling, proposal implementation. This approach to enforcement highlights the importance of court decisions.

While the basis for the recommended 8-Step Conservative Determination Method is a review of relevant issues from U.S. court cases, it is not intended that its application be restricted to the United States. The spirit and intent of NEPA is similar to that of environmental provisions of other nations in that all intend to provide decision makers with more complete and relevant information as to the environmental impacts of their actions. Several nations have recognized the importance of the assessment of cumulative effects. The decisions relative to U.S. court cases as to inclusion or exclusion of a proposal may not be applicable outside the U.S., however, the issues themselves have broader applicability.

Careful consideration of the issues presented in this analysis will further refine the scoping process in CEA regardless of the regulatory framework in which the assessor operates.

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Chapter 4

Air Quality Cumulative Effects Assessment -- Selection of Quantification Models

ABSTRACT

Air quality modeling provides a scientific means for relating source emissions and atmospheric processes, thus project-related effects on air quality can be quantified using appropriate air quality modeling techniques. This study presents an evaluation and determination of the applicability of various air quality quantification techniques within cumulative effects assessment (CEA). Air quality CEA needs are briefly discussed and six criteria questions relating to effects quantification are developed and applied to eleven classes of air quality models. A qualitative decision approach applied to the suitability determination resulted in the identification of three model classes that fully meet the criteria requirements for, and desirable attributes of, cumulative air quality effects quantification. The classes are: Simple Area Source, Rollback, and Box models. Other modeling classes are also identified that employ techniques useful for adaptation to CEA.

BACKGROUND

Any efforts undertaken to control the effects of human activity on the environment must include management strategies for the acceptable use of available resources. For example, elements of the physical environment, including soil, water, and air, are primary resources that require proper management. More specifically, an air quality management system should include source emissions, meteorological observations, air quality data, and air quality models as its basic components (Szepesi, 1989). Utilizing these basic

components, prediction and assessment of air quality effects resulting from development activities should be one aspect of an effective air quality management program.

Air quality is one of the most common physical environment media addressed in environmental impact assessment (EIA) and, therefore, should also be of concern in cumulative effects assessment (CEA). Air quality modeling provides a scientific means of relating source emissions and the atmospheric processes discovered through meteorological observation to provide estimates of resultant ambient air quality (Szepesi, 1989). Air quality models are available and useful for: (1) establishing emission control legislation; (2) evaluating proposed emission control techniques and strategies; (3) selecting locations of future emission sources to minimize effects; (4) planning air pollution episode control activities; and (5) assessing responsibility for existing air pollution concentration levels (Zannetti, 1990). Modeling is often required as part of construction and operation permit processes to demonstrate that ambient air quality standards will be attained. With regard to future activities, modeling is about the only method available for determining air quality effects (Turner, 1994). However, modeling has often been criticized as being inferior to actual monitoring as a representation of real world conditions. Conversely, Zannetti (1990) noted that while monitoring data are indispensable for inferring theories or parameters and calibrating or validating computer simulation packages, their spatial and temporal resolution is generally insufficient to qualify them as truly representing actual air quality conditions.

This paper is presented in three sections: (1) modeling needs relative to air quality CEA and how to evaluate existing models relative to those needs; (2) air quality modeling classifications, regulatory requirements, quantitative prediction uncertainty, validation and

calibration, and software applicability; and (3) an evaluation of existing model classes to determine those most appropriate to CEA, followed by a discussion of the three types of usable models. The section on modeling needs includes a method for qualitatively evaluating model types to determine their suitability to air quality CEA. The air quality modeling section summarizes current classes of models and presents a model classification hierarchy to provide a sense of how a particular model class fits within the whole. The regulatory requirements discussion includes the U.S. Environmental Protection Agency (USEPA) recommendations for the treatment of uncertainty, or error. Finally, the CEA applicability section employs a qualitative decision approach for the determination of which model classes are appropriate for use in air quality CEA.

MODELING NEEDS IN CEA -- Qualitative Decision Criteria

Qualitative comparison selections can be made based on the identification of decision criteria (or desirable attributes) and display of the candidate methods (e.g., model classes) in conjunction with those criteria (or attributes). Once this evaluation has been conducted for each candidate method, the "best choice" can be identified based on the comparison results and sound professional judgment (Canter, 1997).

Adequate CEA of air quality requires consideration of past, present, and reasonably foreseeable future actions (RFFAs), within an appropriate temporal and spatial boundary framework. Inclusion of RFFAs in the analysis introduces the requirement to forecast anticipated, but not guaranteed, future effects. The spatial boundaries determined for the assessment must be reasonable with respect to: (1) the anticipated geographical range of the effects; (2) the administrative, or political, reach of the assessing agency regarding decision

making power; and (3) access to internal and external, or other, agency activity planning information. The temporal boundaries determined must be reasonable with respect to the capabilities of the forecasting methods employed and the level of confidence that the anticipated activity is not only possible, but probable. Defining CEA to include these future planned activities infers the uncertainty, and possible limitations, of the data available on the anticipated air quality effects. Thus, the following six decision criteria (or desirable attributes) for the qualitative comparison approach were developed in part based on these inherent uncertainties.

(1) The quantitative method employed should be simple to use and not resource intensive.

Whether included as part of an environmental assessment (EA), environmental impact statement (EIS), or comprehensive development planning document, air quality CEA is only one part of a study that typically must be accomplished within predetermined time and resource constraints. Several quantification measures currently available are complex, time consuming, and require specific computer hardware and software to conduct the calculations. They provide detailed, complicated outputs that can be difficult to assimilate and convey to decision makers. Since CEA, by definition, includes the consideration of forecasted, probable, but not necessarily definitive, future activities, a practical approach would be to use simple, easily understood, methods that expediently provide the assessor with an assessment of the effects resulting from various scenarios.

(2) The quantitative method can provide acceptably accurate results without extensive, detailed input data.

Information available relative to the RFFAs required to be included in the CEA may be limited to only a brief statement of the need for the action and the general scale and location. Most air quality quantification methods require specific emission source data inputs. The level of uncertainty, or the error factor, of the predicted results is dependent on the accuracy of the input data. Due to lack of source information on RFFAs, methods requiring multiple, specific input parameter estimates, provide greater likelihood for variations in uncertainty linked to the accuracy of each estimate. Therefore, the accuracy of the air quality prediction is dependent on the ability of the assessor to predict input data such as stack height, exit gas temperature and velocity, operational limits, and principle component percentages of the emissions. Given accurate input data, the uncertainty of the more complex methods tends to be lower;

however, due to generalizations and assumptions in the fundamental calculations, the simpler methods will result in uncertainties, or error factors, with less variability.

(3) The quantification method should allow consideration of the relation of activity emissions to established emission and/or ambient air quality standards.

In order to evaluate the significance of the cumulative effects (CEs) to air quality resulting from proposed and existing emission sources, and in the comparison of alternatives, it is helpful to apply some type of rating (or comparison) to the predicted effects. For air quality, legally enforceable emissions and ambient air quality standards exist. Expanding their application to include CEA is practical in that it avoids the added confusion that could result from the development, application, and interpretation of some new rating scheme. Therefore, prudence dictates the use of air quality CE quantification measures that facilitate the comparison of predictions to existing standards.

(4) The quantification method should be usable for forecasting future air quality concentrations and/or activity emission levels.

CEA requires that past, present, and RFFAs be evaluated together. In order to comply with the requirement to assess the CEs of future activities on air quality, it is necessary to estimate what emissions or air quality effects those combined future actions could produce.

(5) The quantification method should be applicable to both local and regional air quality and/or emission level calculations.

Due to atmospheric dispersion, pollutant concentrations resulting from any given source tend to decrease with increasing distance. The result is that the potential for harm resulting from a single activity, or group of activities in close proximity, may differ from that of the effect to the entire region. It is therefore, important that regional and local effects, and their associated significance, are determined separately. Local calculations refer to the general area around the source, or group of sources, that would be immediately impacted by the "plume" of the emissions. Regional calculations refer to the general area in which the emission sources are located that is typically represented by the "ambient" pollution levels. This may be a city, county, air quality control region, or geographic airshed.

(6) The quantification method should focus on the prediction and assessment of long-term (annual) average effects rather than short-term (hourly) worst-case effects.

Specific, and immediate, worst-case analysis of the air quality effects of any federal action proposal will be evaluated in the project specific impact assessment portion of an EA or EIS. Since CEA includes those forecasted,

future events previously discussed, its focus is more on trend analysis and incremental change over time. The detail of the short-term analysis does not need to be repeated in the CEA. Rather, the CEA should present a holistic view of the long-term trends in air quality resulting from all activities within the predetermined boundaries.

AIR QUALITY MODELING -- Model Classifications

Air quality models have been classified by the modeling technique, or approach, used to simulate the real world conditions. Figure 4.1 illustrates an overall hierarchical structure for model classifications which was developed through a compilation of model classifications presented by Seinfeld (1986), Szepesi (1989), Zannetti (1990), and the USEPA (1993). Summary descriptions of the primary classifications of air quality models are presented in Tables 4.1, 4.2, and 4.3. Each of the air quality model types, or classifications, includes modeling techniques developed to provide insight into a specific air quality issue. It is possible, that some other specific modeling techniques (not discussed herein) can also be applied, perhaps in combinations or with minor modifications, to air quality CEA.

AIR QUALITY MODELING -- Regulatory Requirements

The utility of air quality and pollutant dispersion modeling has been recognized by the USEPA. Modeling requirements have been incorporated into several sections of the air program regulations. States are required to project future emissions and ambient air pollutant concentrations in air quality maintenance areas (AQMA) and other areas in order to prevent the significant deterioration of air quality (USEPA, 1993). The control strategy guidelines for the development and implementation of a state implementation plan (SIP) include requirements for the demonstration of the adequacy of the plan. The plans must

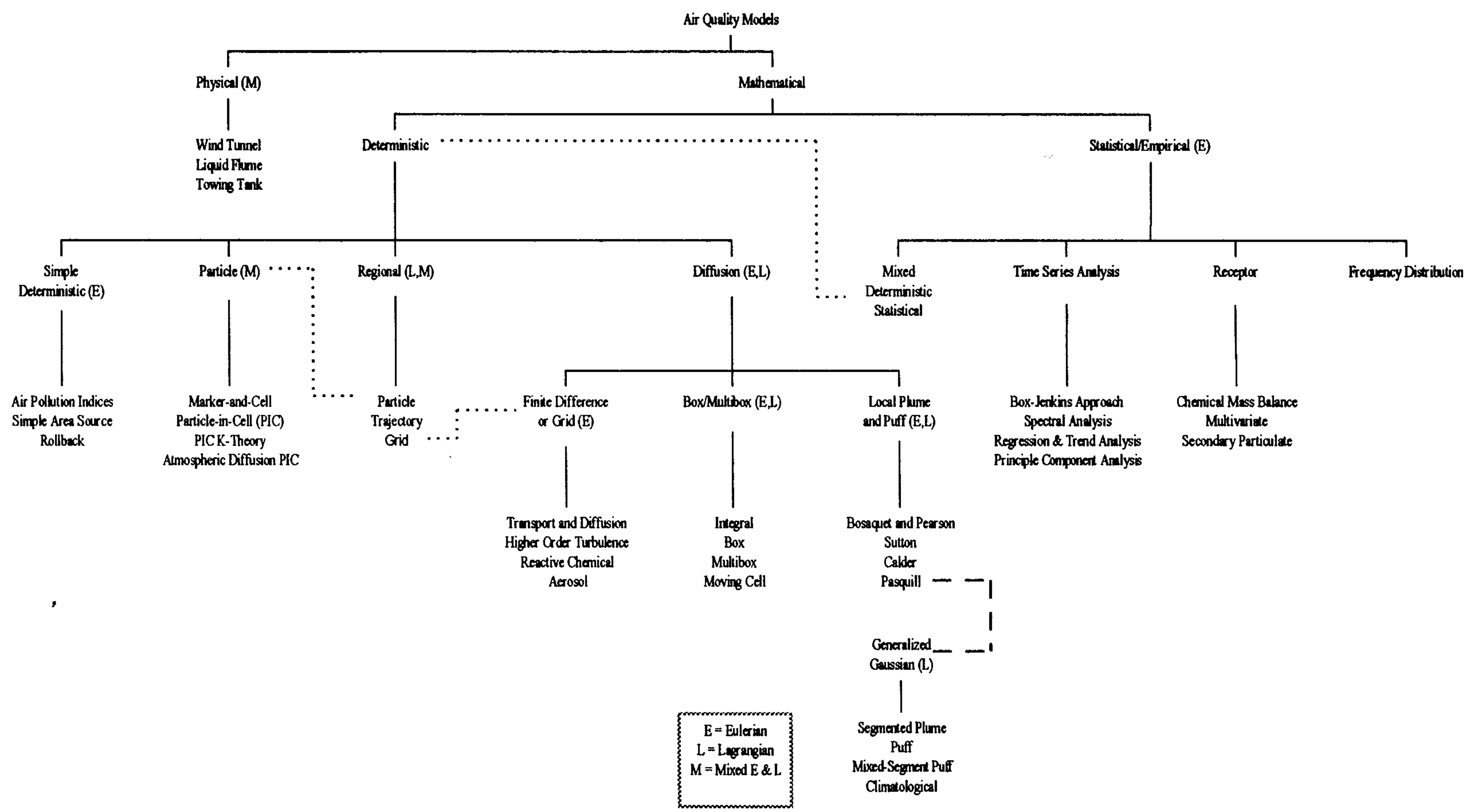

Figure 4.1: Air Quality Model Classification

Table 4.1: Description of Major Air Quality Model Classifications

Physical Models - small scale, laboratory representations of actual phenomena (Zannetti, 1990). Types of physical models include wind tunnels, liquid flumes and towing tanks. **Wind Tunnels** - have been employed to evaluate building wake effects (Szepesi, 1989). **Liquid Flumes** - have been used to investigate the mixing and reentrainment of plumes resulting from multiple mechanical draft cooling towers (Szepesi, 1989). **Towing Tanks** - have been used to simulate pollutant flow and dispersion around and through saddles between mountain peaks (Szepesi, 1989).
Mathematical Models - a set of analytical or numerical algorithms that describe the physical and chemical aspects of the actual phenomena (Zannetti, 1990). The two primary categories of mathematical air quality modeling are deterministic and statistical. **Deterministic Mathematical Models** - those based on fundamental mathematical descriptions of cause and effect atmospheric process relationships (Zannetti, 1990). The primary categories of deterministic models include: simple deterministic, particle, regional, and diffusion models (see Table 2) **Statistical Mathematical Models** - also referred to as empirical, are based upon semiempirical statistical relationships among available data and measurements (Zannetti, 1990). The primary categories of statistical models include: time series analysis, receptor, and frequency distribution models (see Table 3). **Mixed Deterministic/Statistical Models** - depending on the availability of statistical data, semiempirical methods and real-time filters can be used to improve the forecasting capability of a deterministic prediction model. Kalman filters have been used to improve the prediction accuracy of air pollution episodes and pollution control simulations (Zannetti, 1990).

Table 4.2: Description of Deterministic Mathematical Model Classifications

Simple Deterministic Models- algebraic relationships based on empirical data (Szepesi, 1989). Includes simple deterministic, particle, regional and diffusion modeling. **Air Pollution Indices** - presents air pollution information, such as pollutant concentration, as a single number or number set (Szepesi, 1989). **Simple Area Source Models** - are based on emission source strength patterns within the area and average wind speed and direction and are useful for initial screening of atmospheric pollutant concentrations in urban areas. (Szepesi, 1989). **Rollback Models** - relate air quality forecasting to historical ambient air quality data and emission growth trends and are used in air quality maintenance planning as an estimation method for determining emissions reductions required to comply with air quality maintenance area standards (Szepesi, 1989).
Particle Models - evaluate pollutant particles as they pass through a Eulerian grid to allow the model to simulate the random motion observed in actual pollutant particle advective movement (Szepesi, 1989). **Marker-and-Cell (MAC)** - employs massless particles to define spatial orientation within the fluid field (Szepesi, 1989). **Particle-in-Cell (PIC)** - modifies the MAC principles to include particle mass in order to evaluate compressible flow problems (Szepesi, 1989). **PIC K-Theory (PICK)** and **Atmospheric Diffusion PIC (ADPIC)** - also include the capability to evaluate the diffusion characteristics of the particles (Szepesi, 1989).
Regional Models - developed to simulate and analyze atmospheric pollutant transport over great distances and areas. Particle, grid, and trajectory models have been modified for application to regional analysis (Szepesi, 1989). **Regional Particle Modeling** can be expensive to conduct and **Regional Grid Modeling** techniques are still in the development stage. **Regional Trajectory Models** have been developed more extensively and provide for simplified Lagrangian calculation of transport and diffusion of either a limited number of distinct emission sources or an agglomeration of sources within a region. (Szepesi, 1989).

Table 4.2 (continued):

Diffusion Modeling - involves Eulerian and Lagrangian mathematical analysis and can be separated into three main sub-categories, box and multibox, finite difference or grid, and local plume and puff (Szepesi, 1989). **Finite Difference or Grid Models**- produces approximations of urban and regional pollutant concentration over an entire grid, rather than just along a given trajectory. They are generally applied to the calculation, by finite difference approximation of transport and diffusion equations, of short-term concentrations of reactive pollutants and pollution episode analysis. Grid modeling techniques are being developed relative to **Transport and Diffusion**, **Higher Order Turbulence**, **Reactive Chemical**, and **Aerosol Modeling** (Szepesi, 1989). **Box/Multibox Models** - includes techniques such as the **Integral**, **Box**, **Multibox**, and **Moving Cell** and are based on calculations using the integral form of the diffusion equation over a volume or region of air associated with: an urban area; a deep valley or basin; or a subvolume of either. This type of analysis assumes that the pollutants and the air are well mixed within the defined volume (Szepesi, 1989). **Local Plume and Puff Models**- are considered to be the most reliable air quality models given the proper diffusion coefficient and wind data inputs. Local plume and puff models have been used in air pollution control strategy evaluation, land use planning, facilities siting, and highway and aircraft use impact assessments (Szepesi, 1989). Various local plume and puff theoretical relationships have been presented by **Bosaquet and Pearson**, **Sutton**, **Calder**, and **Pasquill**. While the form may vary, each is considered a valid approximation approach to localized pollutant dispersion. **Gaussian Models** - derived from the **Pasquill** theories, are the most common of the local plume and puff. They approximate a binormal distribution of the dispersion characteristics of atmospheric pollutants.. The Gaussian equation can be applied to point, line, area, and volume sources. It has been applied to simulate time-varying pollutant concentration fields with assumptions of a series of steady-state emissions and meteorological conditions to present a separate stationary pollutant concentration field for each time period. This is referred to as **Climatological Modeling**. Progressive change in wind speed and direction and multiple receptor locations can be evaluated using the **Segmented Plume Model**. Other applications of the Gaussian equations include the **Puff Model** and the **Mixed-Segment Puff Model**. These models address non-stationary emissions in variable dispersion conditions, however, puff methods can also simulate low wind or calm conditions (Zannetti, 1990).

Table 4.3: Description of Statistical Mathematical Model Classifications

Time Series Analysis - can be used to determine the variability of and correlation between pollution and meteorological data and also to forecast future concentrations of pollutants based on past and current concentrations combined with meteorological data (Szepesi, 1989). **Box-Jenkins Approach** - considered to be the most cost effective of the time series analysis approaches and has been applied to the evaluation of meteorological and air quality measurement patterns (Zannetti, 1990). **Spectral Analysis** - provides the assessor with a means of identifying particular cycles in the data (Zannetti, 1990). **Regression and Trend Analysis** - allows the evaluator to fit the known data to a line or curve and use it to forecast or project future activity (Zannetti, 1990). **Principle Component Analysis** - incorporates the same evaluative techniques as in regression analysis, however in this case, the principle meteorological data and pollution components observed are used to predict other pollutant concentrations (Zannetti, 1990).
Receptor Modeling - evaluates air pollutant concentrations from the opposite view of other modeling techniques. It observes ambient concentration at the receptor and works back to the emission sources, without reconstructing the dispersion pattern, and determines the appropriate proportion of the receptor concentration that is attributable to each source (Zannetti, 1990). **Chemical Mass Balance (CMB) Receptor Models** - models can be used for primary pollution source tracking (Zannetti, 1990). **Multivariate Receptor Models** - combine CMB with factor analysis. Factor analysis is a tool in statistics that uses empirical orthogonal functions to evaluate quantity variance with minimal factors (Szepesi, 1989). **Secondary Particulate Receptor Models** - modifications, or hybrids, of receptor models useful, for example, in transport and deposition of sulfates (Zannetti, 1990).
Frequency Distribution Models - evaluate the frequency of occurrence of a concentration of an air pollutant that exceeds an established air quality standard or exceeds some other level that is determined to be of significant interest (Zannetti, 1990).

demonstrate that the measures, rules, and regulations contained within it are adequate for the provision of timely attainment and maintenance of the national standards (USEPA, 1993).

The adequacy must be demonstrated by means of applicable air quality models, data bases, and other requirements specified in the *Guideline on Air Quality Models* (USEPA, 1978). All estimates of ambient concentrations required under the prevention of significant deterioration (PSD) of air quality are also required to be based on the modeling methods presented in these guidelines. However, where reference is made to the use of the modeling procedures specified in the *Guideline on Air Quality Models,* the regulations also state:

> Where an air quality impact model specified in the "Guideline on Air Quality Models (Revised)" (1986) and Supplement A (1987) are inappropriate, the model may be modified or another model substituted. Such a modification or substitution of a model may be made on a case-by-case basis or, where appropriate, on a generic basis for a specific state program (USEPA, 1993).

The *Guideline on Air Quality Models* and the regulatory requirements for model usage for demonstration of projected future emissions and ambient pollutant concentrations imply that the USEPA has confidence in the information provided with respect to its utility in environmental decisionmaking. This does not mean, however, that air quality models are accepted with complete certainty as error free.

AIR QUALITY MODELING -- Model Uncertainty and Error

There are several sources of error and/or uncertainty in pollutant concentration estimates obtained from air quality models. For example, emissions data inputs to the models may be in error due to incorrect source strength and location, unaccounted for emission rate variability, stack parameter uncertainties, or errors in plume rise calculations. Meteorological data errors include: incorrect wind speed and direction, poorly specified

dispersion parameters, and incorrect atmospheric thermal structure determinations. The model itself may not be representative of the specific problem due to incomplete knowledge of chemical and physical interactions of gases and particles, incorrect formulation of removal processes, and poorly specified boundary conditions (Szepesi, 1989). No model, regardless of the efforts taken to minimize error, will provide predictions that are identical to observed effects.

Air pollution models vary from simple methods, with few input parameters, to complex methods that include a large number of parameters. The more complex the model, the lower the natural, or stochastic, uncertainty. However, the larger the number of input parameters, the greater the opportunity for data input error (Zannetti, 1990). Therefore, the goal of the air quality effects assessor, when using these predictive models, is to select a model that fits the available data in order to minimize the overall model uncertainty shown in Figure 4.2.

The USEPA provides a discussion on model uncertainty in Appendix W to 40 CFR Part 51 - *Guideline on Air Quality Models* (Revised in 1993). The guide states that there has been increasing reliance on concentration estimates from models as the basis for regulatory decisions on permits and emission control requirements. The USEPA has recognized the need, therefore, to know the accuracy of the estimates that are provided through modeling (USEPA, 1993). Several studies have been conducted to examine model accuracy.

> The results of these studies are not surprising. Basically, they confirm what leading atmospheric scientists have said for some time: (1) models are more reliable for estimating longer time-averaged concentrations than for estimating short-term concentrations at specific locations; and (2) the models are reasonably reliable in estimating the magnitude of highest concentrations, occurring sometime, somewhere within the area (USEPA, 1993).

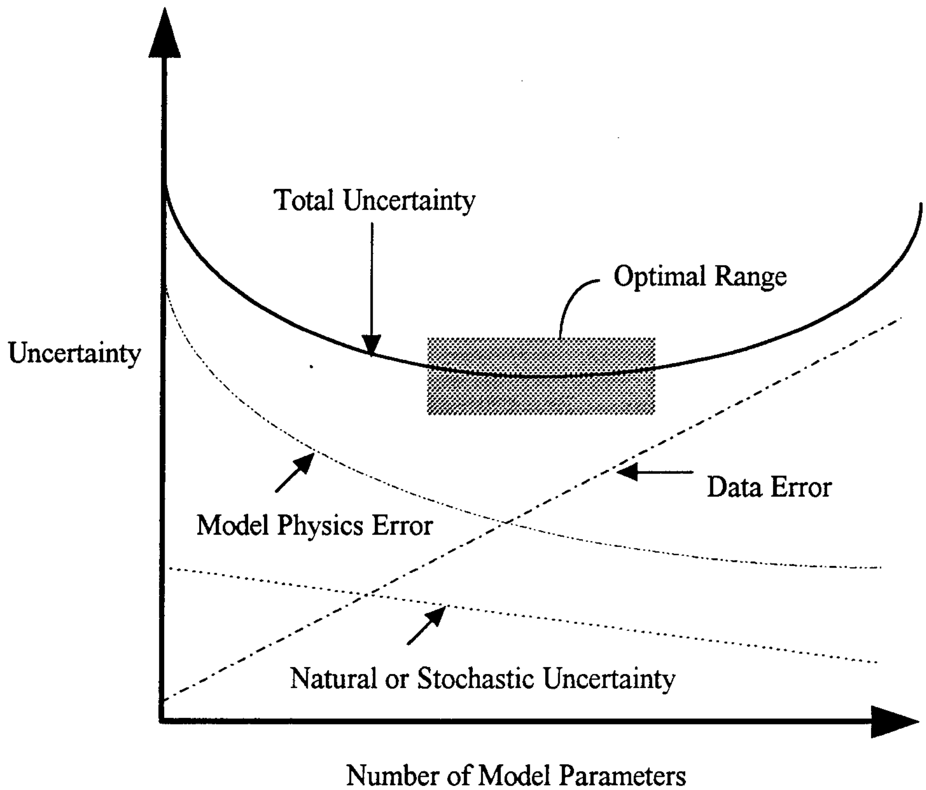

Figure 4.2: Graphical Representation of Model Uncertainty (adapted from Zannetti, 1990)

Quantification of the accuracy, or uncertainty, associated with model estimates used in decisionmaking is desirable, but often lacking. Communication between modelers and decision makers is vital to ensure that the applicability and value of modeling to decisionmaking, as well as the uncertainties and limitations, are understood (USEPA, 1993). Models are increasingly being used to estimate the social costs of emissions so that they can be compared to abatement costs and also to act as a framework for organizing information for improved communication to decision makers and the public (Szepesi, 1989). This permits decision makers to combine the scientific information obtained from the model with respect to the physical environment with the information on the socioeconomic impacts of the activity in order to make sound environmental decisions in the context of development planning.

AIR QUALITY MODELING -- Model Validation/Calibration

The USEPA states that "any application of an air quality model may have deficiencies which cause estimated concentrations to be in error" (USEPA, 1978). The accuracy of a model must be determined in order to promote a sense of confidence in the predicted results.

> When any analytical technique is employed, the analyst is responsible for recognizing and quantifying limitations in the accuracy, precision and sensitivity of the procedure. Thus, in all applications of models, an effort should be made to identify the reliability of the model estimates for that particular area or similar areas and to determine the magnitude and sources of error associated with the use of the model" (USEPA, 1978).

Although this discussion was originally focused on air quality modeling for emissions permitting issues, it is no less valid for that conducted for CEA purposes.

Two options are presented by the USEPA for determination of error within models: validation and calibration. Model validation, the preferred method, is conducted through a series of five analytical steps (USEPA, 1978): (1) comparison of estimates with measured data; (2) determination of the cause of the discrepancies; (3) correction and improvement to data bases; (4) modification, if necessary, of the model to improve performance; and (5) documentation of the measured accuracy. Statistical methods available for validation include, but are not limited to, skill scores, contingency tables, correlation analysis, time series and spatial analysis (USEPA, 1978).

Due to data, time, or other resource limitations within the EIA process, it may not always be possible to conduct a complete model validation. Therefore, a limited procedure, calibration, is available. Calibration is defined as the process of identifying systematic errors and applying a correction factor. Regression analysis or other statistical techniques can be used to adjust the model estimates. Calibration is widely used for long-term, multi-source models but is not recommended for short-term models (USEPA, 1978).

AIR QUALITY MODELING -- Software Applicability

Computer software applications have been developed based on several of the model classes. It is beyond the scope of this paper to address all available software; however, many software items are available within the USEPA standardized User's Network for Applied Modeling of Air Pollution (UNAMAP) system (Brophy, 1991). The majority of the air pollution computer models that are recommended for use by the USEPA are based on the Gaussian plume equation. This type of modeling, commonly referred to as dispersion

modeling, requires a relatively high degree of accuracy in the emission parameter inputs. This is necessary to assure the reliability of the modeling results (Sadar, 1993).

Many software programs are integral parts of comprehensive emergency response planning or hazardous waste management packages. They are usually developed to meet the needs of a specific industry. However, even the more generic packages are often too comprehensive for those only interested in air pollutant concentration predictions (Brophy, 1991).

Even where specific model types are identified for application to CEA needs, the input data requirements are often much more specific than what is available within a forecasted proposal. As noted earlier, lack of detail increases the uncertainty of the predicted results. However, as mentioned above in criterion 2, attempting to estimate the unavailable data introduces variability in the error factor linked to the estimating skills of the individual assessor. Even such simple, conservative, preliminary screening methods as the SCREEN3 model (USEPA, 1995) can require input data more refined than what is available to the cumulative effects assessor.

As a result, the simpler, hand calculation methods that incorporate multiple assumptions, therefore requiring fewer, more generalized inputs, may be as reliable as the more detailed, computerized packages where arbitrary uncertainties would be introduced in "predicting" the required input data. Allowing each assessor to individually influence the level of uncertainty, based on the accuracy of input parameter "predictions," limits the ability to incorporate the results of one assessment, by reference, into another to present cumulative issues. The simpler methods may have a larger inherent error factor than the

more complex methods; however, the removal of the uncertainty variation potential in the simple methods facilitates reproducible, and therefore comparable, results.

AIR QUALITY MODELS FOR CEA -- Qualitative Comparison Results

Through a qualitative comparison approach, the six decision criteria (or desirable attributes) described earlier were applied to the previously summarized eleven air quality model types, or classifications. Table 4.4 presents the decision criteria, the rating scale, and the results of the consideration of each model type.

The results of the qualitative comparison indicate that three model types fully meet the six criteria for application to CEA. They are: Simple Area Source, Rollback, and Box. Further information on the three types are included in the following sections. Note that the Multibox model type is only restricted from this list due to its complexity in calculation and resource, or data, requirements. Given the appropriate situation, it too could be applied to air quality CEA.

AIR QUALITY MODELS FOR CEA -- Simple Area Source Models

Simple area source models are useful for screening level analyses of atmospheric pollutant concentrations in urban areas. Primarily, this type of evaluation is based on emission source strength patterns within the area and average wind speed and direction. Gifford and Hanna presented a simple area source equation in 1973 given by (Szepesi, 1989):

$$C = \frac{c_1 Q}{U}$$

Table 4.4: Qualitative Comparison of Models for CEA Application

Air Quality Model Class	Criteria 1	2	3	4	5	6
Physical						
Wind Tunnel	○	⊗	○	○	○	○
Liquid Flume	○	⊗	○	○	○	○
Towing Tank	○	⊗	○	○	○	○
Mathematical (Deterministic)						
Simple Deterministic						
Air Pollution Indices	●	●	●	●	●	○
Simple Area Source	●	●	●	●	●	●
Rollback	●	●	●	●	●	●
Particle						
Marker-and-Cell	○	○	○	○	⊗	○
Particle-in-Cell	○	○	○	○	⊗	○
PIC K-theory	○	○	○	○	⊗	○
Atmospheric Diffusion PIC	○	○	○	○	⊗	○
Regional						
Particle	○	○	●	●	⊗	⊗
Trajectory	○	○	●	●	⊗	⊗
Grid	○	○	●	●	⊗	⊗
Finite Difference and Grid						
Transport and Diffusion	○	○	●	●	●	⊗
Higher Order Turbulence	○	○	●	●	●	⊗
Reactive Chemical	○	○	●	●	●	⊗
Aerosol	○	○	●	●	●	⊗
Box/Multibox						
Integral	●	●	⊗	⊗	⊗	○
Box	●	●	●	●	●	●
Multibox	⊗	●	●	●	●	●
Moving Cell	○	⊗	●	●	●	●
Local Plume and Puff (Generalized Gaussian)						
Segmented Plume	●	⊗	●	●	○	●
Puff	●	●	●	●	○	○
Mixed Segment Puff	●	⊗	●	●	○	○
Climatological	●	●	●	●	○	●

Table 4.4 (continued):

Air Quality Model Class	Criteria 1	2	3	4	5	6
Mathematical (Statistical/Empirical)						
Mixed Deterministic/Statistical	O	O	●	●	●	⊗
Time Series Analysis						
Box-Jenkins Approach	●	●	●	●	●	O
Spectral Analysis	●	●	●	●	●	O
Regression and Trend Analysis	●	●	●	●	●	O
Principle Component Analysis	●	●	●	●	●	O
Receptor						
Chemical Mass Balance	⊗	⊗	⊗	O	⊗	⊗
Multivariate	O	⊗	⊗	O	⊗	⊗
Secondary Particulate	O	⊗	⊗	O	⊗	⊗
Frequency Distribution	●	●	●	O	●	O

Criteria:

1. Simple to use, not resource intensive.
2. Can provide accurate results without extensive, detailed input data.
3. Allows consideration of relation of activity emissions to established emission and/or ambient air quality standards.
4. Can be used to forecast future air quality/emission levels.
5. Can be applied to local and regional air quality/emission level evaluations.
6. Can be used to focus on long term (annual) average effects rather than just short term (hourly) worst-case effects.

Legend:

● fully meets criteria
⊗ partially meets criteria
O does not meet criteria

where

C = annual average air pollution concentration
Q = source strength per unit area
U = annual average wind speed
c_1 = parameter weakly dependent on city size

One expression for calculating c_1 is:

$$c_1 = \sqrt{2/\pi}\, X^{1-b}\left[a(1-b)\right]^{-1}$$

where

X = distance from receptor to the upwind edge of the area source
a,b = constants defined by the vertical atmospheric diffusion length $\sigma_z = aX^b$.

Regarding the suitability of simple area source models to CEA, it was determined through this analysis that this group fully meets all the criteria requirements. The model parameters are easily obtainable and can be estimated for various time periods and spatial settings to provide estimated future concentrations over a range limited only by the availability of input data.

AIR QUALITY MODELS FOR CEA -- Rollback Models

Rollback models relate air quality forecasting to historical ambient air quality data and emission growth trends. This type of model has been used in air quality maintenance area planning as an estimation method for determining emissions reductions required to comply with air quality maintenance area standards. The simple form of the model estimates future pollutant concentrations using the equation (Szepesi, 1989):

$$C_F = B + kE_F$$

where

C_F = projected concentration
B = background concentration

E_F = future emissions estimate
k = a proportionality factor which incorporates meteorology, source distribution, and other source-receptor variances.

One expression for calculating k, based on present emissions and observed maximum pollutant concentrations, is given as:

$$k = \left(\frac{C_P - B}{E_P} \right)$$

where

C_P = maximum pollutant concentration
E_P = present emissions.

The assumptions inherent in the application of rollback models include: measured maximum concentrations represent the actual maximum in the study area; maximum predicted ambient concentrations are not inconsistent with meteorological conditions at the time and location of the maximum concentration measurements; pollutants are nonreactive; and growth factors can be applied in a spatially homogeneous manner to a distribution of pollutants over the study area that does not undergo temporal transformation (Szepesi, 1989). While the method is titled "rollback," the temporal direction in which the model is applied is irrelevant. The model can be used to project future emissions based on present ambient concentrations or to determine historical emission growth rates based on present ambient concentrations and known past ambient concentrations.

Given these assumptions, rollback models were determined to be suited to application to CEA. This method does, however, require greater knowledge about the subject area than the simple area source models. Accurate data relative to the "maximum pollutant concentration" is necessary to ensure that the appropriate projections can be determined for future scenarios.

AIR QUALITY MODELS FOR CEA -- Box Models

The simple form of the box model is mathematically expressed by the equation (Canter, 1996):

$$C = \frac{Qt}{xyz}$$

where

C = average concentration of pollutant (< 20 μm diameter if modeling particulates), μg/m^3
Q = flow rate of pollutant (< 20 μm diameter if modeling particulates) from emission source, μg/sec
t = time period for which uniform mixing assumption is valid, sec
x = downwind dimension of box, m
y = crosswind dimension of box, m
z = vertical dimension of box, m

The box model is graphically depicted in Figure 4.3. The dimensions of the box are determined based on average wind speed and terrain for x, average wind speed source configuration and terrain for y, and limiting inversion height and terrain for z. Box models can be used for single and multiple point, line, and area sources or combinations of these source types (Canter, 1996).

Box models share attributes with simple area source and rollback models in that the format of the equations allow ease of information assimilation. All three model classes employ generalizations of complex meteorological and emission source conditions to minimize errors in application resulting from numerous varying, or even inaccurate, estimations of complex conditions. An additional attractive feature of the box model is the ease presenting the results spatially. Since the model directly incorporates the dimensions of the evaluated area, decision makers are provided with insight as to the predicted effects relative to specific geographic boundaries or landmarks. The box model also provides the

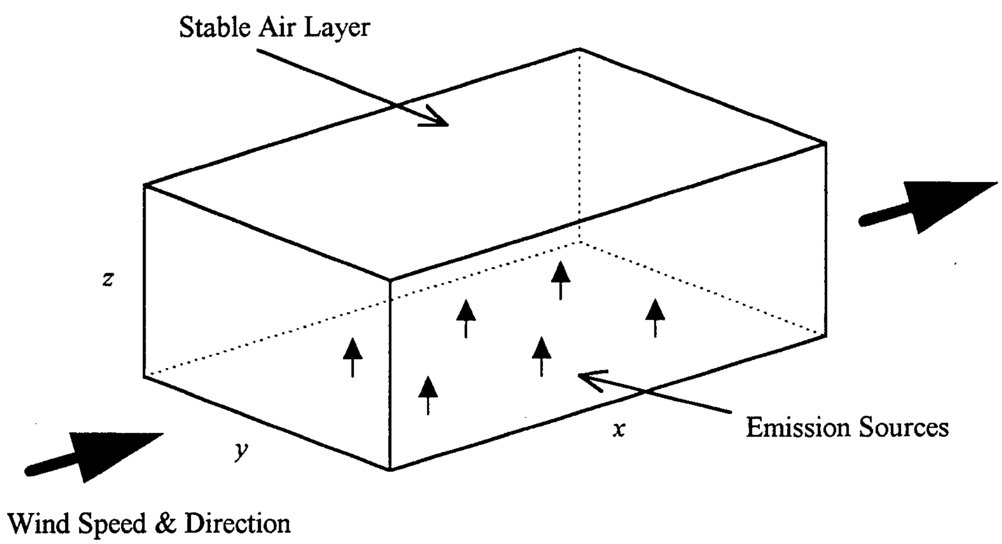

Figure 4.3: Simple Box Model (adapted from Canter, 1996)

opportunity to address effects over arbitrarily defined regions or those based on meteorological influence on the emitted pollutants.

The multibox model expands the concept of the box model by dividing the evaluated volume of air, or airshed, into 2-dimensional or 3-dimensional arrays of boxes. Individual box properties, such as inversion height, wind speed, and volume, can vary between boxes. The modeled pollutants travel between adjacent boxes through advective forces only. No diffusion across box boundaries is permitted in this method. Multibox models have the advantage over single box models in that time variation of inversion heights can be incorporated, and the multiple box dimensions can be selected to conform to local topography. The negative aspects of the multibox model include: failure to address vertical diffusion; and excessive mathematical calculation requirements. However, modifications have been incorporated into the multibox model for specific applications to include vertical pollutant concentration distribution (Szepesi, 1989).

DISCUSSION AND CONCLUSIONS

Environmental pollution does not restrict itself to the initial media to which it is released. Contaminants released to the air can precipitate and deposit on soil or surface waters. Other contaminants released to ground or surface water can find their way into plants or animals and to soil where wind, erosion, and human activities can re-entrain them into the atmosphere. As a consequence, an holistic modeling approach for CEA needs to consider intermedia transport of pollutants. A CEA methodology for air quality does not necessarily need to include multimedia transport calculations within itself, however, consideration should be given to using the outputs of air quality modeling as inputs for CEA

models for other media. Therefore, a CEA method developed for air quality should incorporate the concepts of multimedia transport modeling as a foundation principle. Once additional research is completed on CEA with regard to other environmental media, the methods could be aggregated into a multimedia system.

The air quality model classes determined herein to be appropriate for CEA (Simple Area Source, Rollback, and Box) are those which do not require extensively detailed input information. Therefore, coupling with existing multimedia transport models would be inappropriate for application at this time. The resource and data requirements for this type of modeling are extensive and would have to be estimated for the forecasted activities. Consideration of multimedia effects and transmedia impacts is important, however, in CEA. Any quantification method developed for air quality CEA should encompass future research where the cumulative air quality effects could be interrelated with other media effects. A simple interrelation technique could consist of incorporation of the air quality impact CE quantification method into a partially coupled, integrated, spatial multimedia model where the calculations could be run independently for each model with executive system control.

It also appears that attributes of other classes of models may be adaptable to CEA. Several other model classifications fully met all but one of the criteria (or attributes). These include the Time Series Analysis statistical models and the Climatological model under the generalized Gaussian local plume and puff category. For these, the theoretical formulae may be applicable, however, input requirement details and spatial analysis restrictions may severely limit the usage of existing packaged software in CEA.

Finally, the results of this study can be summarized into five concluding points as to the applicability of existing classes of air quality models to air quality CE quantification:

(1) There are existing air quality effect quantification methods that can be applied, or adapted, to air quality CEA. They include: the simple area source, rollback, and box models. There are no currently available physical models suitable to air quality CEA.

(2) Most available software applications are too specific or too detailed to be of use in air quality CEA since the input data estimations may be impossible to obtain or may result in fluctuations to model uncertainty. This severely limits the comparative study value of the predicted CEs.

(3) In accordance with the USEPA requirements for approval of air quality models, and to lend credibility to the predicted results, any air quality CE quantification model should be validated or calibrated in accordance with the USEPA guidelines.

(4) Discussion of the CE quantification model uncertainty, or error factor, within the study report, will provide the decision maker with a sense of the validity of the predicted results.

(5) And, once developed, appropriate individual media CE quantification methods can be integrated into a multi-media CEA executive protocol similar to that of the multi-media pollutant transport and fate modeling techniques.

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Chapter 5

Significance Determination for Cumulative Air Quality Effects

ABSTRACT

The environmental impact assessment (EIA) process requires the determination of the significance of an action's impact in context with its surroundings. Cumulative effects assessment (CEA) evaluates proposed actions in context with other past, present, and reasonably foreseeable future activities. Therefore, determination of the cumulative significance of human intervention in the environment is necessary to meet the objectives of both CEA and EIA. This paper presents a systematic procedure for the evaluation of one aspect of cumulative effects, air quality. The described procedure was developed through adaptation of existing EIA significance evaluation methods combined with expert opinion. The procedure includes 18 factors for evaluation relative to specific pollutants and spatial boundaries. A significance score results from the assignment of importance weights and intensity levels to the 18 factors. Based on anticipated results, techniques for evaluating and implementing new opportunities in mitigation are presented.

INTRODUCTION

The purpose of the National Environmental Policy Act (NEPA) in the United States is to require federal agencies to consider environmental issues and values when making decisions regarding major actions (Mandelker, 1997). Much of the environmental aspect of these decisions is linked to the significance of the effect, or impact, of the proposed activity. In fact, the requirement to prepare an environmental impact statement (EIS) hinges on the

potential for the proposed activity to significantly affect the quality of the human environment (Canter and Canty, 1993). A key issue, then, in environmental impact assessment (EIA) is to determine the significance of the environmental impacts and apply that information to decision making. From a strictly environmental point of view, the preferred decision is one that results in the least amount of damage to the environment and best preserves and enhances the natural, historic, and cultural resources in the area (Kreske, 1996). Disagreement over the significance of an environmental impact is one of the primary focal points for NEPA-related legal actions against United States federal agencies (Canter and Canty, 1993).

Determination of cumulative effects significance differs from that of project-level impact significance. In a cumulative effects assessment (CEA), multiple activities must be considered. The timing and location of these proposals can influence the spatial and temporal boundaries considered. Whereas a project-level assessment considers the environmental consequences of a single action on its local surroundings, a CEA needs to address the long-term significance of the original proposal and other proposals connected either by proponent agency planning, geographic proximity, or affected resource. A CEA addresses not only the ability of the environment to assimilate the impacts of the original proposal, but also its influence on development sustainability. Ambient air quality is an important environmental component in both EIA and CEA, hence, the purpose of this paper is to describe a procedure for assessing the significance of cumulative effects on air quality resulting from multiple activities. The procedure could be modified for other environmental media or resources.

The paper is organized around three topics. The first is a review of pertinent literature on project-level impact significance determination and evaluations. The second combines ideals from this literature review with professional expertise in the formulation of an air quality cumulative effect significance evaluation procedure. And the third presents a framework for the evaluation and implementation of mitigation measures for reducing significant adverse cumulative effects on air quality.

PROJECT-LEVEL IMPACT SIGNIFICANCE

Current practice related to project-level impact significance determination is based on regulatory guidance, court decisions and interpretations, several types of developed methods and approaches, and consideration of the uncertainties of impact predictions.

Regulatory Guidance

In the United States, the determination that a project significantly impacts the environment requires the consideration of both the context in which the impact occurs and that impact's intensity (Council on Environmental Quality, 1996). The Council on Environmental Quality (CEQ) definitions of context and intensity are presented in Table 5.1. Even with these definitions, controversy remains. For example, some agencies refuse to include the term "significant" in environmental documents because it assumes a judgment, while other agencies require that every impact be labeled as "significant" or "nonsignificant" (Marriott, 1997). While the latter case may be more informative than the former, a thorough discussion of the significance of the predicted impacts in light of the context and intensity issues would provide more complete information for use in decision making.

Table 5.1: Context and Intensity Considerations Related to Significance Determinations Under NEPA (Council on Environmental Quality, 1996)

(a) *Context.* This means that the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of the proposed action. For instance, in the case of a site-specific action, significance would usually depend upon the effects on the locale rather than in the world as a whole. Both short- and long-term effects are relevant.

(b) *Intensity.* This refers to the severity of impact. Reasonable officials must bear in mind that more than one agency may make decisions about partial aspects of a major action. The following should be considered in evaluating intensity:

(1) Impacts that may be both beneficial and adverse. A significant effect may exist even if the Federal agency believes that on balance the effect will be beneficial.

(2) The degree to which the proposed action affects public health or safety.

(3) Unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas.

(4) The degree to which the effects on the quality of the human environment are likely to be highly controversial.

(5) The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks.

(6) The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration.

(7) Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts.

(8) The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural, or historical resources.

(9) The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973.

(10) Whether the action threatens a violation of Federal, State, or local law or the requirements imposed for the protection of the environment.

To assist in developing the decision making information necessary to comply with the requirements of NEPA, and the need to develop legally defensible significance determination decision documentation, multiple philosophical discussions and determination approaches are available; examples include Canter (1996a), Wood (1995), and Kreske (1996). This is not surprising due to the abundance of literature on project-based EIA. As presented in the CEQ definitions, significance is influenced by the intensity of the impact as well as the contextual framework in which it occurs. Accordingly, in the United States, there exists no formal test, or set of standardized quantitative thresholds, for use in determining the significance of the environmental impacts of any project. Determination of the threshold between an impact that may "significantly effect" the environment and one that does not will include professional judgment, consideration of local conditions and public opinions, and guidance provided by court decisions and interpretations.

Court Decisions and Interpretations

The United States court system has repeatedly been tasked to interpret the term "significant," such as in the NEPA-related case of *Hanly v. Kleindienst*, and in the State of Washington's State Environmental Policy Act (SEPA) related case of *Norway Hill Preservation & Protection Association v. King County Council* (Preston, 1990). In both cases, the court noted that at least two relevant factors must be examined: (1) the extent to which the action would cause adverse environmental effects in excess of those created by existing activities in the area; and (2) the absolute quantitative adverse environmental effects of the activity, including the cumulative harm resulting from its contribution to existing adverse conditions or uses in the area (Preston, 1990). These two factors are presented as

minimum considerations, however, they provide a foundation for the development of significance determination approaches. Additionally, in *Natural Resources Defense Council Inc. v. Grant*, the court stated:

> The standard 'significantly affecting the quality of the human environment' can be construed as having an important or meaningful effect, direct or indirect, upon a broad range of aspects of the human environment. The cumulative impact with other projects must be considered. Any action that substantially affects, beneficially or detrimentally, the depth or course of streams, plant life, wildlife, habitats, fish and the soil and air 'significantly affects the quality of the human environment' (Preston, 1990).

In each of the three cases, the court stated the requirement to consider the cumulative effect as a contributor to the significance of the impact. In general, the courts have rejected specific size or monetary factors as significance thresholds (Kreske, 1996). Possibly, this is to ensure that professional judgment, impact context, and public opinion remain as part of the determination.

Methods and Approaches

In addition to the courts, environmental practitioners and researchers have exerted considerable effort into the development of significance determination methods and approaches. For example, Canter and Canty (1993) suggested a sequenced approach based on a review of the CEQ regulations combined with various international definitions and perspectives. The intent is to apply the series of questions (see Table 5.2), in the order given, to the proposed activity. The answers to each question can be used to determine if there is a significant impact. Furthermore, specific questions could be developed, based on individual project-level assessment needs.

Table 5.2: Sequenced Approach Significance Determination Questions (after Canter and Canty, 1993)

1. Does the proposed activity cause impacts that exceed the definition of significant impacts as contained in applicable laws, regulations, and executive orders?
2. Is a quantitative threshold criterion exceeded in terms of activity type, size, or cost?
3. Is the activity located in a protected habitat or land-use zone, or within a land use exclusionary zone?
4. Is the activity expected to violate pertinent environmental laws, regulations, policies, and/or executive orders?
5. What is the anticipated percent change in applicable environmental factors from the proposed activity? Will the changes be within the normal variability of the factors? What is the sensitivity of the environment to the anticipated changes; or is the environment susceptible or resilient to change? Will the carrying capacity of the resource be exceeded?
6. Are there sensitive human, living, or inanimate receptors to the environmental stresses resulting from the proposed activity?
7. Can the anticipated negative impacts be mitigated in a cost-effective manner?
8. What is the professional judgment of experts in the pertinent substantive areas, such as water quality, ecology, planing, archeology, and landscape architecture?
9. Are there public concerns due to the impact risks of the proposed activity?
10. Are there cumulative effects that that should be considered or impacts related to future phases of the proposed activity and associated cumulative effects?

The U.S. Army Corps of Engineers has produced A Guide To The Analysis of Significance (1983). This guide outlines a three step process for determining the significance of a proposed activity's impacts on environmental resources. The steps for the overall process are: (1) identify which resources are significant; (2) judge the significance of the resource changes resulting from the proposed activity; and (3) determine the consequences of the impact significance (U.S. Army Corps of Engineers, 1983). For each step in determining significance, the guide provides test questions and key points of consideration.

In Step 1, identification of resource significance, the guide indicates that the determination is founded in legal, political and public, and professional judgment criteria (U.S. Army Corps of Engineers, 1983). Key points relating to each of the criteria for Step 1 are presented in Table 5.3. The second step, judgment of resource change significance, again uses legal, political and public, and professional judgment criteria. However, a new set of key points are presented (see Table 5.4). Finally, for Step 3, the determination of the consequences of impact significance, interpretation of the significant impacts requires one or more of the following: (1) the preparation of or inclusion in an EIS; (2) mitigation of the impact; and (3) a change in the alternative selection (U.S. Army Corps of Engineers, 1983).

The Canadian Federal Environmental Assessment Review Office (FEARO) presented a three step process for the determination of significant adverse environmental effects. The three steps are (Federal Environmental Assessment Review Office, 1992): (1) determine if the environmental effects are adverse; (2) if adverse, determine if the adverse effects are significant; and (3) if significant, determine if the effects are likely. Step 1 involves identifying the adverse effects of the proposal. Step 2 is conducted through

Table 5.3: Criteria for Determining Resource Significance (after U.S. Army Corps of Engineers, 1983)

Legal Criteria

- Resources are significant if protected by law, policy, plan, control, or regulation
- Resources are significant if part of a legally defined management unit (e.g. wild and scenic river)
- The level of legal protection (federal, state, local) can affect significance level
- Past and predicted future legal status should be examined
- Legally significant resources are often publicly, politically, and professionally significant

Political and Public Criteria

- Political significance is influenced by public perception
- The level of political concern (federal, state, local) can affect significance level
- Depending on level of origin, political significance can increase resource significance determined by other tests
- Politically defined significant resources may become legally significant
- Conflict over resource use, resource availability, resource demand, and knowledge about resource can lead to political and public significance recognition
- Resources can be identified as significant by any segment of the public, and the significance may be perceived rather than real
- The scoping process uses public participation to identify significant issues and de-emphasize nonsignificant issues
- Early resource significance determinations can be changed through public input
- Key questions in assessing resource significance based on public input include:
  (1) Who says the resource is significant?
  (2) How many say the resource is significant?
  (3) What is the history and future use expectations for the resource in this region of influence (ROI)?
  (4) What is the value of the resource to the public?
  (5) Does the planning team judge the significance as real or perceived?
  (6) If perceived, can the perception be changed?
  (7) Are additional studies needed to support or refute the significance determination
  (8) Can an assumption of significance be made with little or no effect on alternative planning?

Professional Criteria

- Professional judgment may be the only basis of recognition for significance, careful documentation is essential
- Key professional judgment questions include:
  (1) What is the past, present, and expected future condition of the resource in the ROI?
  (2) What is the condition of the resource in local, regional, state, and national context?
  (3) What is the size and extent of the resource?
  (4) Is the resource scarce?
  (5) Can a monetary value be placed on the resource? If so, what is it?
  (6) What are the biological, physical, and socioeconomic attributes of the resource?
- Key questions on when to conduct additional studies include:
  (1) Assuming the resource is significant, is the resource likely to be significantly impacted by the proposed activity?
  (2) What are the tradeoffs of assuming significance?
  (3) Will planned studies provide the answers to resource significance questions?
  (4) What are the costs of the study?
  (5) Is additional baseline data needed?
  (6) Is further study necessary to make a responsible professional judgment commensurate with other aspects of planning or can the further study be deferred until a later stage?

Table 5.4: Criteria for Determining the Significance of Resource Changes (after U.S. Army Corps of Engineers, 1983)

Legal Criteria

- Impacts may be significant if they occur to resources protected by law
- Legally protected resources may have legally defined processes for determining significance
- The level of legal protection can affect the impact significance determination
- Past, present, and predicted future legal status should be examined in significance determination
- Impacts may be significant if a legal precedent is established
- Legally defined significant impacts are commonly publicly, politically, and professionally significant

Political and Public Criteria

- Political significance is influenced by public perception
- Impacts may become significant if a political precedent is established
- The level of political concern (federal, state, local) can affect significance
- Impacts can be identified as significant by any segment of the public, and the significance may be perceived rather than real
- Depending on level of origin, political significance can increase impact significance determined by other tests
- The scoping process uses public participation to identify significant impact issues to be examined
- Early impact significance determinations can be changed through public input
- Impacts publicly recognized as significant may become politically recognized
- Political or public recognition of impact significance may be more restrictive than legal recognition
- Key questions in assessing impact significance based on public input include:
  (1) Who says the impact is significant and why?
  (2) How many say the impact is significant?
  (3) Does the planning team judge the significance as real or perceived?
  (4) If perceived, can the perception be changed?
  (5) Are additional studies needed to support or refute the significance determination
  (6) Can an assumption of significance be made with little or no effect on alternative planning?
  (7) Is the public willing to pursue litigative action over the impact?

Table 5.4 (continued):

<u>Professional Criteria</u>

- Professional judgment may be the only basis of recognition for significance, careful documentation is essential
- Professional judgment of impact significance involves some risk and educated guessing where information is lacking or because of time, money, or state-of-the-art limitations
- Professional expertise or opinion must often be relied upon to determine impact significance thresholds
- Professional judgment significance determinations can be made with assistance from other professionals, literature, and real world experiences
- Common sense is a major feature of professional judgment
- Key professional judgment questions include:
  (1) What biological/physical/socioeconomic attributes of the resource are being impacted?
  (2) What is the extent, magnitude, and duration of the impact?
  (3) To what degree does the impact affect public health or safety?
  (4) What is the probability of the impact occurring?
  (5) Is the impact on the human environment highly uncertain or involve unique or unknown risks?
  (6) When will the impact occur?
  (7) What is the type of the impact (direct, indirect; beneficial, adverse; temporary, permanent; short-term, long term)?
  (8) Does the impact become significant when considered cumulatively with other impacts?
  (9) Does the impact result in a violation of established criteria?
  (10) What is the past, present, and anticipated future condition of the impacted resource?
  (11) What is the context and intensity of the impact and its magnitude/importance on local, regional, state, or national scales?
  (12) Is the impact occurring to resources unique to the ROI?
  (13) Is the impact likely to be highly controversial?
  (14) Will the impact result in the loss or destruction of notable scientific, cultural, or historic resources?
  (15) Will the impact result in the irreversible or irretrievable commitment of resources?
  (16) Will the impact affect long-term productivity of the human environment?
  (17) Can the impact be easily and successfully mitigated?
  (18) What is the cost of the impact?
- The professional must decide when it is appropriate to conduct additional studies to adequately determine impact significance
- Key questions on when to conduct additional studies include:
  (1) What is the probability that the impact will affect alternative selection?
  (2) Is the impact unavoidable and, if so, will it jeopardize the feasibility of the alternative?
  (3) What are the tradeoffs of assuming significance and modifying the alternative, mitigating the impact, or avoiding the impact versus the cost of the additional study? What is the probability that the study will find the impact to be significant?
  (4) Is an additional study required to develop mitigation? Will mitigation attempts succeed?
  (5) What is the state-of-the-art? Will the additional study provide the answers to questions about impact significance?
  (6) Is further study necessary to fulfill a legal or political requirement, or to avoid controversy?
  (7) Is further study necessary to make a responsible professional judgment commensurate with other aspects of planning or can the further study be deferred until a later stage?

evaluation of the adverse environmental effects relative to several criteria as shown in Table 5.5. Finally, in Step 3, likelihood is determined by considering the probability of occurrence combined with the scientific uncertainty of the predictive method employed (Federal Environmental Assessment Review Office, 1992).

In addition to conceptual approaches for determining the significance of an environmental impact, specific methods have also been developed. Questionnaire checklists can be used to identify impacts and mitigation possibilities, and may also provide an impact classification scale ranging from highly adverse to highly beneficial (Glasson, Therivel, and Chadwick, 1994). A second type of checklist which provides input into significance determinations is the threshold of concern (TOC) checklist. This checklist includes a list of environmental resources and a quantitative or descriptive threshold for each where assessors should become concerned about an impact.

Matrices are another commonly used tool for identifying and comparing impacts. Typically, a matrix will present project activities on one axis and environmental resources or factors on the other. Each activity is then rated against each resource or factor. Magnitude matrices, in addition to impact identification, provide information on impact intensity, importance (includes beneficial/adverse information), and/or time frame of occurrence. Time-dependent matrices can be used to present impact magnitude variations over time (Glasson, Therivel, and Chadwick, 1994). More complicated matrix methods, such as the stepped matrix (cross-impact matrix), can be used to address secondary and tertiary impacts. In this type of application, environmental resource components are displayed against other environmental resource components. This allows the presentation of the consequences of initial effects on other resources not directly impacted by the activity

Table 5.5: FEARO Significance Determination Criteria (adapted from Federal Environmental Assessment Review Office, 1992)

Magnitude - Refers to the severity of the effect. If the effect is major or catastrophic, then it is significant. If the effect is minor, or inconsequential then it may be insignificant. Consider the extent to which the proposal could trigger or contribute to cumulative effects.

Geographic Extent - Widespread effects may be significant, localized effects may be insignificant. Consider influence to environmental resources outside the proposal area (e.g. acid deposition, long range transport of atmospheric pollutants. Also consider contribution to cumulative effects.

Duration and Frequency - Long term or frequent effects may be significant. Future response to environmental degradation should be considered (e.g. human carcinogens).

Reversible or Irreversible - Reversible effects may be less significant than irreversible ones. Consider planning of activity decommissioning when evaluating reversibility.

Ecological Context - Adverse effects may be significant if they occur in areas that have already been adversely affected by human activities and/or are ecologically fragile and have little resilience to imposed stress.

(Canter, 1996a). Since the basis of this matrix is a simple matrix rating environmental attributes against proposal activities, any information format used in the initial matrix (magnitude, importance, time-dependency) can be carried throughout the stepped matrix.

Within a matrix, the issue of impact importance is often addressed as a weighting factor applied to the magnitude of the impact. Importance weightings can be assigned to both the environmental resource components of the matrix and the proposal activities. The impact magnitude of the proposal activity on the environmental resource component is assessed and then multiplied by the appropriate weighting(s) to determine the overall total impact (Glasson, Therivel, and Chadwick, 1994). By assigning importance weightings, the assessor has identified, at least for the local region of influence, the significance of each impacted resource in context with all other impacted resources. When importance weightings are assigned to the activities, this identifies the preference, or utility, of each activity to the project proponent.

Air Quality Significance Determination

Generic approaches, such as those described above, are typically refined, or adapted, to address the impacts of a proposed activity relative to each affected environmental medium or resource. Air quality is one of the environmental media commonly considered to be significant by institutional, political, and public entities and, as such, it has received attention as to what criteria should be included in project-level significance determinations.

Professional judgment can be used to evaluate significance based on the percentage changes from baseline conditions in terms of pollutant emission levels, exposed human

population, and/or a pollutant standards index (Canter, 1996a). Additionally, many pollutants have ambient air quality or emission limitation standards that can be used as a basis for interpretation. Elsom (1995) suggests that if the planned development is predicted to increase pollutant levels close to or in excess of air quality standards, mitigation proposals should be included. And, when the increases remain well below the standard, meaningful representations of the activity impact, such as a percentage change in emissions or ambient concentration, needs to be included in the discussion.

Canter (1993) suggested delineations in significance for percentage increases in air pollutant emissions when combined with existing air quality information. The emissions categories presented are:

> Category A -- the increase resulting from the proposed activity is equal to or greater than 10% of the local existing inventory for a specific pollutant, or for all pollutants combined if a total inventory is used.
>
> Category B -- the increase is from 5 to 9% of the local existing inventory for a specific pollutant, or for all pollutants combined if a total inventory is used.
>
> Category C -- the increase is from 0 to 4% of the local existing inventory for a specific pollutant, or for all pollutants combined if a total inventory is used.

Further, five categories are used for the interpretation of project activity effects in comparison to ambient air quality standards. The categories are:

> Category 1 -- the existing pollutant concentration is greater than the allowable standard(s).
>
> Category 2 -- the existing concentration is from 50 to 100% of the standard(s).
>
> Category 3 -- the existing concentration is from 25 to 49% of the standard(s).

Category 4 -- the existing concentration is from 0 to 24% of the standard(s).

Category 5 -- no data on air quality is available but there is no reason to suspect problems relative to attainment status.

Finally, combinations of the first set of categories (A,B,C) with the second (1 through 5) presents a contextual approach to significance. For example, greater significance should be assigned to a Category A effect occurring in a Category 1 area than the same effect in an area classified as Category 2.

Air quality significance interpretations should also incorporate specific effects resulting from the pollutants produced by the activity. This can include effects on sensitive human or agricultural receptors (Canter, 1996a). Additionally, air pollution emissions can produce secondary damaging effects such as photochemical oxidant formation, cause stratospheric ozone depletion, or contribute to acid deposition. Air quality value, in context with the implications of potential damage resulting from atmospheric pollution, is subject to the local value system of the impacted public. Public participation in air quality significance determinations, as with all other environmental resources, can have considerable influence.

Uncertainty Considerations

"Environmental impact statements often appear more certain in their predictions than they should" (Glasson, Therivel, and Chadwick, 1994). Predictive techniques include potential uncertainties related to the estimations of actual conditions where observed data is not readily available and in the forecasting of future events and effects. There are several potential uncertainties related to impact prediction, including mathematical model application (Canter, 1996b). Even though all predictions have some element of uncertainty,

only in recent years has such uncertainty begun to be recognized in the EIA process (Glasson, Therivel, and Chadwick, 1994).

Categories for EIA uncertainty have been developed to help assessors identify error and uncertainty within environmental studies and predictions. One approach is to evaluate modeling errors, natural stochasticity, and parameter errors; another approach is to divide EIA uncertainties into two main categories: data uncertainty, and decision uncertainty (Petts and Eduljee, 1994). Table 5.6 outlines specific issues relative to each. CEA requirements add a new dimension to uncertainty as the assessor attempts to determine historic activities, and predict and evaluate the present and reasonably foreseeable future activities of multiple government agencies and the private sector (Canter, 1996b)

Methods have been proposed as to how uncertainty should be handled in EIA. Gilpin (1995) suggests six considerations for addressing uncertainty in significance determinations in environmental decision making (see Table 5.7). However, there are no quantitative thresholds presented as to when uncertainty should be considered to be acceptable or unacceptable. Further, Gilpin (1995) suggests that EIA professionals should not present decision makers with complex, technical data. Instead, the decision makers should be given a synopsis of the analysis including the assessor's professional judgment relative to impact significance (based in part on uncertainty) and recommendations as to appropriate action.

Other approaches to uncertainty include considering issues of probability and confidence in predictions. This can be presented as quantitative data, such as the confidence interval for a predicted value, or as a qualitative discussion. Additionally, techniques such as a sensitivity analysis and the preparation of an uncertainty report can be useful. The

Table 5.6: Data and Decision Uncertainty Issues in the EIA Process (after Petts and Eduljee, 1994)

Data Uncertainty - Project definition and characteristics - Incomplete and/or irrelevant baseline information - Model error - Problems in defining dose-response relationships - Inaccurate collection of data Decision Uncertainty - Failure to conduct adequate scoping - Use of formalized weighting and scoring systems - Data manipulation to accommodate differing interests - Pressure to present the "worst case" analysis - Decisions made external to the EIA process that influence the EIA decisions or perceptions - Lack of well defined strategic plans and policies needed for contextual decision making

Table 5.7: Uncertainty Considerations for EIA Decision Making (after Gilpin, 1995)

- If the uncertainties are great and there is no way to reduce them to acceptable levels, within a framework of conditions, reject the proposal.
- If the uncertainties are great, but could be reduced with further study over a short period of time, and the remaining uncertainties could be controlled through reasonable and enforceable conditions, defer the proposal until the further studies are completed.
- If the uncertainties might be reduced through further studies, and it is likely that the outcomes would not be serious and could be controlled by conditions, then the proposal could be approved, subject to the restrictive conditions and the results of the further studies.
- If the uncertainties are tolerable, approve the proposal, subject to conditions including performance audits at specified intervals.
- Adopt the precautionary principle. Defined by Gilpin as - A guiding rule in EIA to protect people and the environment against future risks, hazards, and adverse impacts, tending to emphasize safety considerations in the occasional absence of clear evidence.
- In all cases of proposal approval, specify criteria for the suspension of hazardous operations and arrangements for review.

uncertainty report is a document, or section of a document, that consolidates all sources of uncertainty identified in the assessment and presents discussions on how they can be reduced. However, it should be noted that only rarely can uncertainty be completely eliminated (Glasson, Therivel, and Chadwick, 1994).

AIR QUALITY CEA SIGNIFICANCE DETERMINATION FACTORS

Since there is no available method specifically designed to address the significance of cumulative air quality effects, relevant air quality issues were addressed to develop a list of factors for application to a systematic significance determination procedure.

An initial list of factors was assembled on typical air quality and cumulative effect issues prevalent in the literature. This initial list was then distributed to a group of eight environmental professionals with experience in these and related areas to provide improvement feedback. The group included university professors, environmental consultants, state air quality regulators, and industrial practitioners. The result is a list of 18 factors (see Table 5.8) determined to be appropriate for consideration in air quality cumulative effect significance determinations. The factors were categorized into 6 functional groups; however, some issues overlap multiple categories. For example, the combination of sulfur dioxide and suspended particulate matter can result in a synergistic adverse health effect. Therefore, it could theoretically fall under two categories: secondary/indirect/synergistic effects, and health effects. Professional judgment must dictate where it is applied for each assessment, particularly where the categories are weighted differently. The following subsections address the functional groups in Table 5.8.

Table 5.8: Significance Determination Factors for Air Quality Cumulative Effects

Pollutant Emissions
- % change in total area emission level of a pollutant
- timing, duration, and rate of emission level change*
- comparison of emission rates to emission permit or rule limitations* (% of sources not meeting requirements)

Ambient Air Quality Standards
- change in ambient concentration*
- timing, duration, and rate of ambient concentration change*
- violation of standards* (federal, state, local)
- influence on air pollution episodes
- influence on current area classification (attainment/non-attainment, maintenance area, prevention of significant deterioration (PSD) area)

Public Perception
- level of concern expressed by public over air quality issues*

Secondary/Indirect/Synergistic Effects
- influence on photochemical pollution level (PPL) potential
- influence on VOC/NO_x ratio
- influence on stratospheric ozone
- influence on global warming
- spatial (transboundary) transport of pollutants (national, global)
- influence on SO_2 & NO_x contribution to acid deposition potential

Human Health
- level of carcinogenic effect
- level of non-carcinogenic effect

Mitigation
- timing/focus of mitigation efforts vs. timing/focus of effects

*Similar to factors typically addressed in project-level EIA.

Note: Sensitive receptors are not listed as a category for inclusion; however, they are addressed. A regional level analysis will typically always have some mix of sensitive receptors (e.g. children, hospital patients, elderly, specific crops, terrestrial vegetation, valued structures or monuments, etc.) that could be affected. Direct consideration of sensitive receptors should be accomplished at the individual project assessment level where local plume concentrations and dimensions can be evaluated. At this level of analysis, consideration of sensitive receptors is included within the considerations of ambient air quality standards and secondary/indirect/synergistic effects.

Pollutant Emissions and Ambient Air Quality Standards

Consideration of the quantity, type, location, and rate of the emitted pollutants, as well as the influence those emissions have on ambient air quality, and ambient air quality standards, are relevant in cumulative effects significance determinations. Quantitative data on emission rates and ambient concentrations are typically determined for individual project assessments. Therefore, the cumulative consideration of the same information allows for direct contextual consideration of the activity within its surroundings. Rates of change over time can identify, or alleviate, concerns of future sustainability in the evaluated area. Multiple, individually insignificant, degradations to the air quality could result in significant damage over time without a cumulative analysis. Evaluations of these direct emissions to the atmosphere also provide input into the determination of some of the resulting secondary and synergistic effects. Additionally, since ambient air quality standards are developed and applied with the intent of preserving human health, considerations of toxic effects, sensitive receptors, and exposure durations are included by default.

Quantitative changes in emission levels or ambient concentrations can provide, at least qualitatively, insight into the change in frequency of air pollution episodes for the evaluated spatial and temporal boundaries. Timing and duration of emissions, or concentration changes, indicates the relative permanence of the damage to the environment. The long-term operational emissions from sources can cause significant degradation to air quality, especially where emission limitations are not being observed by currently operating sources. Short-term effects may be less significant than those expected to last for long periods. Also, the rate of change resulting from multiple activities can be important when compared to the current classification of the air quality. An area classified for prevention of

significant deterioration, for example, may find that it must adjust the timing of its planned development to avoid violation of degradation allotment limitations.

Public Participation

Public concern over the consequences of development activities will always be an important consideration. The public is often expected to support the planned activities, either through consumerism, employment functions, or public derived funding. The public also must live with the consequences of these activities throughout various aspects of their lives. Since most development activities depend, to some degree, on the public, it is important to evaluate the level of concern over the consequences. This is critical in a cumulative evaluation since the effects may occur gradually. Public risk perception may be that an individual activity is of little concern. Without the cumulative analysis of all activities proposed in the area over multiple years, the public may not perceive the total risk. Alternately, public outrage over perceived environmental degradation can be curbed if various publics are participants in the decision making process and are allowed to evaluate the potential for damage against the benefits of the proposed activities. Full disclosure of beneficial and detrimental consequences and inclusion of public input in alternative selection helps eliminate overreaction and reduces the perceived risk of events.

Secondary/Indirect/Synergistic Effects

Larger-scale air pollution issues such as photochemical smog, acid deposition, stratospheric ozone depletion, and global warming are often overlooked in project-level assessments unless there is a previously identified concern. This is not surprising since an

individual activity contribution to such large scale effects will almost always be too small to quantify. When a cumulative analysis is conducted at a city, or regional, level, some information relative to these larger issues can be developed. For example, evaluation of the VOC/NO_x ratio can guide urban ozone mitigation planning, and qualitative determinations relative to the potential for increased photochemical oxidant formation can be made based on precursor emission level changes. Emissions of SO_2 and NO_x, and resultant ambient concentrations, or emissions, also provide insight into an area-wide and downwind potential for acid deposition. At a regional level, evaluation of the influence on stratospheric ozone depletion or greenhouse gas contributions to global warming are difficult, if not impossible. However, they are included as determination factors for consideration at larger spatial analysis scales (e.g., national evaluations).

Transport of pollutants across air quality control region, state, or national boundaries is not a new issue. This should be evaluated in any project-level impact assessment where there is a likelihood of measurable transport. However, a cumulative analysis adds a new emphasis to transboundary effects. Cumulative analyses are typically conducted relative to a predetermined spatial scale (boundary). Air quality effects on that scale may, for example, result in a significant increase in the concentration of a particular pollutant. If the spatial scale is then expanded to include the activities of a larger area, the significance of that pollutant concentration can change. What was significant on a local level, may not be significant, when considered in conjunction with other activities, on a regional level. However, if the local analysis shows a small, relatively insignificant increase in one or more pollutants, those increases could be significant at a regional level if the previously existing downwind concentrations were at or near limiting standards.

Health Effects

Information of importance under health effects includes: the toxicity of the pollutant compared to dose-response information; the type of effect; and the timeframe in which the resulting damage is observed compared to the time of exposure. Dose-response information is typically available for atmospheric pollutants as a listing of the effects resulting from exposure. These results are obtained from laboratory experiments or epidemiological studies involving humans and/or animals. A valuable conceptual tool, when available, is the dose-response curve (see Figure 5.1). With a dose-response curve, the assessor can determine the rate of change in the response as each new activity alters the concentration over time. Curve A in Figure 5.1 presents a response where slight changes in the dose at low concentrations produces large changes in the response. Curve B show a relation in which the response it proportional to the dose. Curve C demonstrates a condition where only small changes in the response are observed for variations in low dosage; however, at higher dosage, the response becomes increasingly more pronounced. Curve D represents an additional proportional response; however, in this case, there is a threshold at which doses below it will not produce any effects (Wilson et al., 1980).

Mitigation

The significance of an adverse effect can be reduced if that effect can be mitigated. Since a cumulative analysis may reveal that the focus of concern for the evaluated region is different than the individual activity-determined focus of concern, the value of mitigation takes on new meaning. At the project level, mitigation of carbon monoxide may alleviate the greatest effect. However, if the small emission of particulate lead from the activity is of

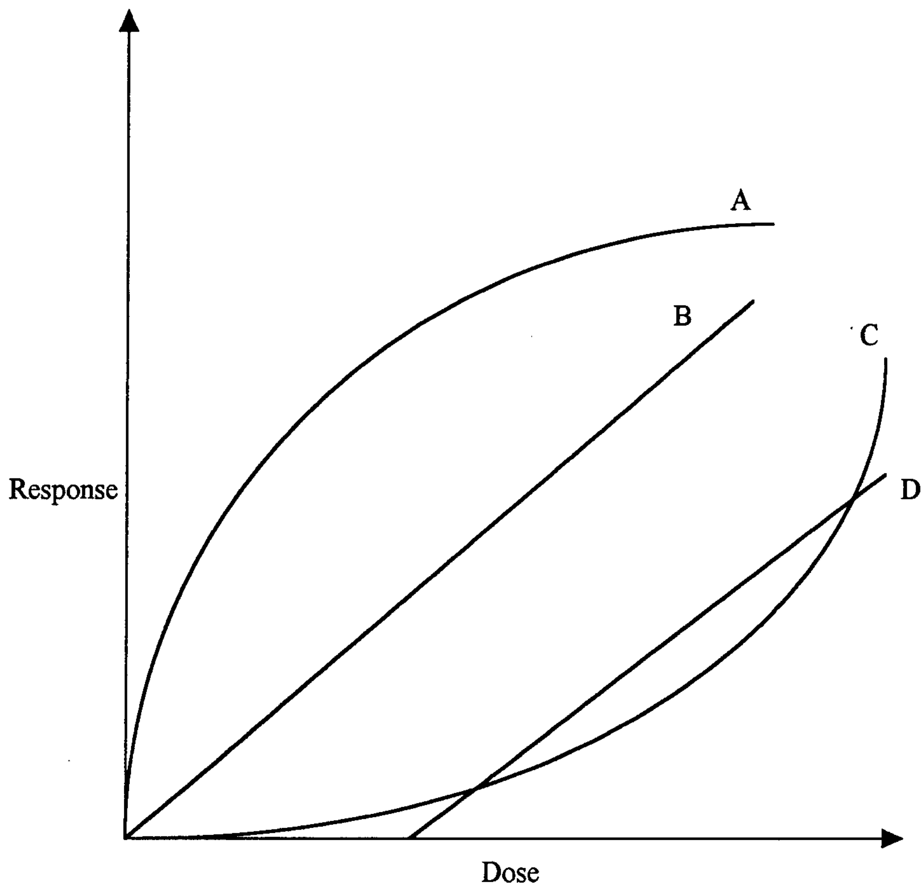

Figure 5.1: Dose-Response Relationships (after Wilson et al., 1980)

greater concern to the regional air quality, mitigation there may have a greater influence on overall air quality effect significance. If mitigation opportunities are expanded to a series of future projects, it may be more important to mitigate the particulate lead from an existing activity than for the new proposal. This option carries with it the opportunity for the project proponent to do a greater service for the human community as well as the concern over timing of the mitigation effort. Mitigation of existing sources is obviously of greater value if it is performed prior to construction and operation of the new source.

Project Concerns vs. Cumulative Concerns

As indicated in Table 5.8, only 6 of the 18 factors determined to be of relevance in a cumulative assessment of air quality are typically addressed in project-level assessments. Project specific assessments will typically address the change in emission level, but only based on the contribution of a single proposal. Comparison to permit rules or limitations is also common; however, the area trends toward compliance may not be addressed. Under the ambient concentration category, it is common to find discussions relating the proposal contributions to ambient levels and comparisons to standards. Also, project-level impact studies usually include public concern relative to air quality issues. The remaining issues presented as being important to a cumulative analysis are unique to the holistic evaluation goals of a human community, regional, or larger level analysis.

AIR QUALITY CEA SIGNIFICANCE SCORING PROCEDURE

Once the factors being considered have been reviewed as to their relevance for a specific CEA study, the next step is to actually apply them to the available air quality

cumulative effect data. This requires that importance weights be assigned to each of the significance factors corresponding to the expert opinion-derived level of importance. Table 5.9 presents a scoring matrix with the final list of factors and importance weights. The factors are assigned high, medium, and low importance levels usable for generic application; however, specific local circumstances may necessitate alterations in the listed importance weightings. For example, the cumulative influence on stratospheric ozone depletion and global warming were determined to be of relatively low importance for a local or regional scale analysis. Such limited scale influences on a global issue would be difficult, if not impossible, to determine. However, if a national or continental scale assessment were conducted, information gathered would be of greater relevance to these effects and, therefore, the significance of the predicted effects would increase. Violation of ambient standards was determined to be of high importance due to the comprehensive environmental protection nature of the established ambient concentration limits. The rationale for placing additional importance on the significance of public concern over air quality issues is that government agencies are, by definition, public servants. Air quality management, community development planning and approval, and the EIA and CEA processes are all driven by government agency activities. Public concern over how public servants accomplish the services required of them by their customers must be held in high regard.

Air quality effects resulting from the combination of all activities in the study area should then be rated as to the intensity of their influence on each factor. Note that some factors may need to be rated for individual pollutants or spatial boundary conditions (e.g., local, regional, national, etc.) to complete the analysis. Recommendations corresponding to three levels of intensity for the 18 factors are presented in Table 5.10. Next, the intensity

Table 5.9: Scoring Matrix for Air Quality Cumulative Effect Significance Determination

Factors	Factor Weighting (a) High importance = 3 Medium importance = 2 Low importance = 1	Cumulative Effect Intensity (b) Large Adverse = 3 Moderate Adverse = 2 Small Adverse = 1 No Adverse Effect or Beneficial Effect = 0	Weighted Effect (axb)
Pollutant Emissions			
% change in emission level	2		
timing, duration, and rate of change	2		
comparison to emission limitations (% noncompliance)	2		
Ambient Air Quality Standards			
change in ambient concentration	2		
timing, duration, and rate of change	2		
violation of standards	3		
influence on air pollution episodes	2		
influence on current area classification	2		
Public Perception			
level of public concern	3		
Secondary/Indirect/Synergistic Effects			
influence on PPL potential	2		
influence on VOC/NO_x ratio	2		
influence on stratospheric ozone	1		
influence on global warming	1		
spatial (transboundary) transport	2		
influence on acid deposition potential	2		
Human Health			
level of carcinogistic effect	2		
level of non-carcinogistic effect	2		
Mitigation			
timing/focus of mitigation vs. timing/focus of effects	2		
			Total =

Note: This matrix should be applied relative to each spatial boundary condition and pollutant addressed in the analysis.

Table 5.10: Intensity Rating Recommendations

Factor	Cumulative Intensity High (3)	Moderate (2)	Low (1)
Pollutant Emissions - % change in emission level	10% or greater increase	5 - 9% increase	< 5% increase
- timing, duration, and rate of change	occurs early in study period, > 5 years duration, high rate of increase	occurs midway through study period, 1 - 5 years duration, moderate rate of increase	occurs late in study period, < 1 year duration, slow rate of increase
- comparison to emission limitations (% noncompliance)	10% or greater	5 - 9%	< 5%
Ambient Air Quality Standards - change in ambient concentration	> 5% increase	1 - 5% increase	< 1% increase
- timing, duration, and rate of change	occurs early in study period, > 5 years duration, high rate of increase	occurs midway through study period, 1 - 5 years duration, moderate rate of increase	occurs late in study period, < 1 year duration, slow rate of increase
- violation of standards	cause new violation	impairs plans to mitigate existing violation	small contribution to existing violation
- influence on air pollution episodes	new occurrence where none observed before or large increase in existing number of episodes	moderate increase in existing episode frequency or required level of response	small increase in existing episode frequency or required level of response
- influence on current area classification	exceeds classification based limits	classification based limits reached	limits future development
Public Perception - level of public concern	high level of concern	some concern	little concern
Secondary/Indirect/Synergistic Effects - influence on PPL potential	10% or greater increase in precursor emissions	5 - 9% increase in precursor emissions	< 5% increase in precursor emissions
- influence on VOC/NO_x ratio	10% or greater increase to limiting pollutant or change of limiting pollutant	5 - 9% increase to limiting pollutant	< 5% increase to limiting pollutant
- influence on stratospheric ozone	large increase in ODC emissions	moderate increase in ODC emissions	small increase in ODC emissions
- influence on global warming	large increase in precursor emissions	moderate increase in precursor emissions	small increase in precursor emissions
- spatial (transboundary) transport	large contribution to downwind area concentration	moderate contribution to downwind area concentration	small contribution to downwind area concentration
- influence on acid deposition potential	large increase in precursor emissions	moderate increase in precursor emissions	small increase in precursor emissions
Human Health - level of carcinogistic effect	known human carcinogen	probable human carcinogen	possible human carcinogen
- level of non-carcinogistic effect (dose response relationships, comparison to thresholds, synergisms, etc)	Air Toxics - concentration above MAAC (or TLV/1000) Others - high likelihood of adverse effect	Air Toxics - concentration at MAAC (or TLV/1000) Others - moderarte likelihood of adverse effect	Air Toxics - measurable conc. below MAAC (or TLV/1000) Others - low but identifiable possibility of adverse effect
Mitigation - timing/focus of mitigation vs. timing/focus of effects	allows for long-term (>5 years) continuance of mitigable effect	allows for continuance of mitigable effect for 1 - 5 years	allows for continuance of mitigable effect for less than one year

ODC = Ozone Depleting Chemical, MAAC = Maximum Allowable Ambient Concentration, TLV = Threshold Limit Value

rating for each factor is multiplied by the assigned importance weight. The results are placed in the "Weighted Effect" column in Table 5.9. Once all "weighted effects" are determined, they are added to yield a single score. The possible range of scores is from 0 to 108. Based on this range, the significance of the corresponding cumulative air quality effect can be judged. The available range of values should first be divided into the following groupings:

0 - 35 (low significance or nonsignificant)

36 - 72 (moderate significance)

73 - 108 (high significance)

Assessments resulting in low "weighted effect" scores can easily be termed as nonsignificant. Where a score is determined to be in the high range, the assessment should clearly state that a significant adverse effect is predicted. However, where assessments result in moderate range scores, professional judgment must be used in applying specific labels. Combined consideration of the cumulative effect with the direct effects related to the proposal originally generating the requirement for the NEPA process may sway the decision. Additionally, consideration of the level of uncertainty in the predictive techniques may influence the score's interpretation.

The results of the significance determination matrix (Table 5.9) should be presented in a summary discussion within the applicable NEPA documents. Separate matrix computations may be needed for each spatial boundary condition, and thus the activities addressed, and each pollutant evaluated. To develop an overall sense of the cumulative air quality significance, the resulting scores relative to each pollutant and boundary condition addressed should be presented together to evaluate intensity level comparisons and emphasis

shifts. This will highlight the importance of individual pollutant effects in each context. Averaging of the scores to obtain a single air quality significance rating is not recommended since this could suppress high and low end values for specific pollutants or boundaries.

Beneficial effects are rated in the scoring matrix in combination with the "no effect" condition to eliminate the potential for a beneficial effect to mathematically "cancel" an adverse effect. Beneficial effects should, however, be considered as a complementary issue. Also, severely adverse effects may be muted by the limitations of the scoring system. To ensure that the contributions of beneficial and severely adverse effects are not masked by the analysis matrix, a short discussion of these effects should be included along with the quantitative rating. If several composite ratings are developed due to shifting boundary conditions, or multiple pollutant analyses, each should be presented.

As noted earlier, scientific uncertainty is found in multiple locations throughout NEPA documents. When assessing air quality effects, uncertainty can be found in the estimation techniques used to determine source emission strength, dispersion characteristics, and ambient concentrations. Potential error related to source emission estimates stems from the prediction of the actual future activity. For example, fugitive dust estimations are based on soil water content, construction vehicle use rates, meteorological conditions, and acreage estimates. Actual conditions can; and typically do; vary from the average data. Pollutant dispersion characteristics and ambient concentrations are typically obtained through mathematical modeling. Inherent assumptions in the models introduce error as can mistakes in input data. Model validation or calibration techniques can be employed to minimize this source of uncertainty.

In a CEA, errors may be compounded by the magnitude of the evaluation. As the assessment predicts effects further into the future, the likelihood decreases that all the activities which might take place in the future time have been properly identified and evaluated. Careful planning can minimize these errors but not eliminate them. Periodic review and updating of the CEA documentation can assist in correcting future activity prediction errors. The direct project effect uncertainties relating to the quantification of pollutant emissions and ambient concentrations can be compounded by the assessment of multiple activities. However, even if uncertain, the cumulative assessment data provides an improved contextual assessment of any given activity than can be obtained from a direct project impact assessment that ignores its relative contribution in context with its surroundings.

The importance of uncertainty relative to cumulative air quality significance determination would be of lesser value without the context of the remainder of the analyses regarding other media (e.g., surface water) or resources. If the results of the air quality significance determination are highly certain, then the information can be relied upon as presenting probable future conditions. However, as the uncertainty increases, one cannot say whether the likelihood is that the future conditions will actually be better or worse than the predictions. Decisions related to alternative selection and mitigation option implementation need to be made in context with the effect on other environmental media and resources. Therefore, the recommended format for handling uncertainty is the preparation of an uncertainty report (the report can be included as an appendix in the impact study document). Once the uncertainties from all predictive techniques are combined, relative

uncertainties can be determined and decisions regarding additional studies or activity modifications can then be made.

CUMULATIVE AIR QUALITY EFFECT MITIGATION

Mitigation measures for reducing air pollutant emissions from specific activities are commonly available. When considering activities cumulatively, within the defined spatial and temporal boundaries, additional mitigation opportunities arise. Evaluation of mitigation options for a group of activities affecting the same environmental resource, such as air quality, allows the assessor to select which activities would provide the greatest emission reductions at the lowest cost. For example, it may be advantageous to defer air pollution mitigation for a project planned for year 2, and later include additional mitigation measures on a project scheduled for year 5. Of course, some pollution control equipment may be legally required for a project regardless of other opportunities.

However, this new mitigation opportunity, or flexibility, should not be used unconditionally. Once it is determined that some type of cumulatively significant adverse air quality effect exists as a result of the area activities, the following five-step approach can be applied:

(1) Conduct a systematic analysis of the pollutant contributions.

(2) Conduct a legal review of the proposed activities.

(3) Identify available mitigation, or pollution prevention, measures.

(4) Determine the cost of each mitigation, or pollution prevention, measure.

(5) Select mitigation option(s) and develop a financing and implementation plan.

The systematic analysis (Step 1) refers to an evaluation of the activities which contributed to the significant effect. For example, assume it is determined that the carbon monoxide (CO) levels are significantly increased over the study period. All activities determined to contribute CO emissions during the study period would be identified and grouped by agency or private sector development. This could include past and present activities as well as future proposals depending on how the temporal boundaries were determined. The resulting lists would provide the percentage contribution as well as the timing of pollutant emissions for each agency or sector. Possible groups to include are: federal, state, and local governments, private industry, and private citizen (or consumer) activities. While the NEPA process is only required for major federal agency actions, the cumulative nature of the effect requires the contextual consideration of non-federal agency contributions.

In Step 2, each activity is reviewed to ensure that any and all legal requirements for emission limitations have been met. These requirements can vary based on geographical location and the attainment status for each pollutant evaluated. If any agency, or activity, is not in compliance with legal standards, modifications to the appropriate projects must be made. Once all activities and activity proposals are in compliance with the applicable legal requirements, the significance determination and mitigation option review can be reaccomplished.

The technical and procedural mitigation and pollution prevention opportunities are identified in Step 3. Options can include: pollution control equipment; process or procedure changes; emissions trading; rescheduling of activities (to avoid short-term

significant effects); or elimination of activities from the plan. Multiple options may be developed for each evaluated activity.

Step 4 involves the determination of the cost of each mitigation, or pollution prevention, option. The intent is to determine the most cost effective options from those determined in Step 3 and provide economic justification for their incorporation into the area activity plans. This can be accomplished through an incremental cost analysis (Orth, 1994). Incremental cost is the increase in cost when the output of the system is increased by one unit. It is an investigation into how the cost of additional output increases as the level of output increases. However, attaching a monetary value to some benefits of mitigation (e.g., improved air quality, public piece of mind, etc.) is subjective if at all achievable. Other considerations, such as the timing of the mitigation relative to the timing of the onset of the activity can reduce the mitigative value. However, incremental cost analysis can provide an essential framework for efficient planning.

Once the costs and benefits of each mitigation measure have been identified, the most cost effective option, or option group, can be selected for implementation in Step 5. It is possible that the most cost effective option will require mitigation for activities other than those of the agency primarily responsible for the significant adverse effect. Financing options may be needed to ensure that each agency pays for their fair share. Finance capital can be obtained through emission fees, construction and operation permits, or sales and property tax increases. Obviously, the success of this entire process is dependent on cooperation between the agencies involved. The alternative to cooperation, however, is to allow the effects to go unmitigated. This can lower the quality of life in the area and possibly bring the area to a point where further development is no longer possible.

CONCLUSIONS

The CEA process, as well as the entire EIA process, is meaningless unless the gathered and derived information can be used in decision making. A key component in information development is the determination of the significance of the predicted effects in context with surrounding activities. To accomplish this, it is vital to provide decision makers with information on the significance of the environmental effects resulting from the total human influence on the study area. One component of this total influence is the cumulative effect on air quality. The weighting-rating matrix procedure described herein was developed from primarily U.S. policy and regulatory guidance; however, the guiding principles can be useful for CEA in all nations.

Determination of the significance of the cumulative air quality effect to an area can be accomplished through evaluation of the air quality issues important to human, ecological, and developmental sustainability. Application of the six categories of factors described herein in a matrix format allows for a structured analysis, coupled with professional judgment, that is practical, defensible, and comparable to direct project impacts. The holistic view of air quality effects significance presented through this approach allows for improved insight into cost effective mitigation opportunities. Presentation of air quality effect issues and mitigation opportunities in this format facilitates understanding and acceptance of decisions made and the associated costs and benefits.

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Chapter 6

Air Quality Cumulative Effects Assessment -- A Practical Example

ABSTRACT

This paper presents a demonstration of air quality cumulative effects assessment methods applied from the perspective of a federal agency's (United States Air Force) influence on a small southwestern city. The methods employed were developed by the authors through: pertinent literature review, legal requirement analysis, expert opinion survey, and case study analysis involving recent environmental assessments and environmental impact statements. The methods are applied to the planned development activities of a U.S. Air Force base combined with the activities of the surrounding community. This case study presents the assumptions needed to overcome difficulties in data collection and analysis and the rationale for the decisions made. Conclusions relating to this example highlight the importance of revisiting steps as necessary and updating the analysis periodically to maintain its currency and value. The result is the development of useful environmental decision making information that can be obtained within the typical time and resource constraints commonly facing assessment professionals.

INTRODUCTION

Multiple methods and techniques have been developed to assist environmental planners in assessing the effects of human activities on their surroundings. A particular issue of current concern is the evaluation of the cumulative effects of proposed actions in relation to nearby past and future actions. However, cumulative effects assessment (CEA)

has been criticized as being too comprehensive and complex to be incorporated into the project-specific impact assessment process (Dixon and Montz, 1995). For example, several applicable theories and methods for conducting CEAs can be found along with ideal attributes that should be included. Seminars, conferences, and even court cases, have contributed to what is considered to be necessary for adequate CEA. Often, however, practitioners tasked with conducting CEAs are left with multiple theories, methods, ideal components, and suggestions that, while valuable, do not demonstrate the rudimentary mechanics of how to get the job done.

This paper presents a practical application of a method to identify and offer resolution for the difficulties associated with data collection, effects prediction, and analysis. The basis is an 8-step method for cumulative air quality effects assessment (CAQEA) proposed by Rumrill and Canter (1998b) (see Table 6.1). These steps incorporate the data collection and evaluation tasks necessary to generate quantitative air quality cumulative effects (CEs) information. By applying the steps to a U.S. Air Force base (AFB), a federal facility subject to the requirements of the National Environmental Policy Act (NEPA), and the surrounding area, quantitative and qualitative data can be developed in a format applicable to significance determination of the effects in context with the direct air quality effects of an individual major action. The intent is for CEs to be compiled as an independent document and incorporated by reference into individual project impact analyses.

The AFB selected represents a typical facility. It is located in the southwestern section of the United States and consists of a single mission wing with typical support structure. It has an active flight line and is not currently scheduled for base closure. The future activities scheduled are typical of AFBs where the intent is to maintain and improve

Table 6.1: Steps for Cumulative Air Quality Effects Assessment (CAQEA) (after Rumrill and Canter, 1998b)

1. Select definition of CE to be applied in the analysis.
2. Determine spatial and temporal boundaries.
3. Determine past, present, and reasonably foreseeable future actions to be included in the analysis.
4. Determine baseline ambient air pollutant concentrations and obtain applicable standards or regulations.
5. Develop quantitative and qualitative emission data estimates for the actions determined in Step 3.
6. Determine quantitative and qualitative changes to baseline air quality (determined in Step 4) resulting from evaluated actions.
7. Evaluate the CE significance in context with the air quality impacts of the action originally generating the NEPA requirement and incorporate that significance into the assessment.
8. Include mitigation opportunities for CEs when discussing specific action impact mitigation.

the current mission capabilities but not take on new mission responsibilities. There are no currently existing mission critical deficiencies. The adjacent city is small (approximately 100,000 residents) but is experiencing gradual linear growth (as projected in the city growth trends report) within a well established industrial and commercial economy. Conducting a study of an AFB located near a small population center with relatively few concerns about ambient air pollution allows for the exploration of various data limitation scenarios and the development of evaluation options to apply to each.

STEP 1 -- DEFINITION SELECTION

Step 1 involves the selection of a definition for cumulative effects (impacts) to be used throughout the study. The intent is to standardize the definition employed by a federal agency and thus minimize the potential for variation between assessors as to their perceptions of the meaning of CEs. The Council on Environmental Quality (CEQ) definition was selected; it states that cumulative impacts (or CEs) result from

> "the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR 1508.7 as found in Council on Environmental Quality, 1996).

The same definition should be applied when considering CEs on other environmental resources as well as in each individual project environmental impact study.

STEP 2 -- BOUNDARY DETERMINATIONS

Step 2 relates to the determination of spatial and temporal boundaries for the analysis. Based on discussions and recommendations in various literature sources, the time frame considered reasonable for air quality CEA for application to an AFB was 10 years; two years of the "past" and eight years of the "future." This determination was based on the availability of past and current air quality data and the relative degree of certainty that could be applied to AFB and local plans for future activity.

Regarding spatial boundaries, consideration was given to both the physical airshed and existing political boundaries. Political boundaries can influence the number and types of future actions, significance determinations, and mitigation decisions. Initially, the political boundaries considered were: (1) the AFB property boundaries; (2) the city limits; and (3) the county in which the AFB and city are located. The airshed boundaries were determined to be linked to the prevailing wind speed and direction. When applying the quantification measures suggested in Rumrill and Canter (1998a), spatial dimensions can be determined by considering the distance a theoretical parcel of air would travel given the prevailing wind speed and direction over a time period considered to be reasonable for uniform mixing assumptions. For this example, multiplying the annual average wind speed of 5.66 m/sec and a typical mixing time of 1 hour resulted in a downwind distance roughly equivalent (approximately 12% larger) to the physical length of the developed land area of the city. Also, while valuable information was obtained from county level sources, insufficient data was available to forecast future development for the entire county. Therefore, the analysis was limited to the effects of the AFB in context with the surrounding city. The total geographical area was approximately 268 sq. km (see Figure 6.1).

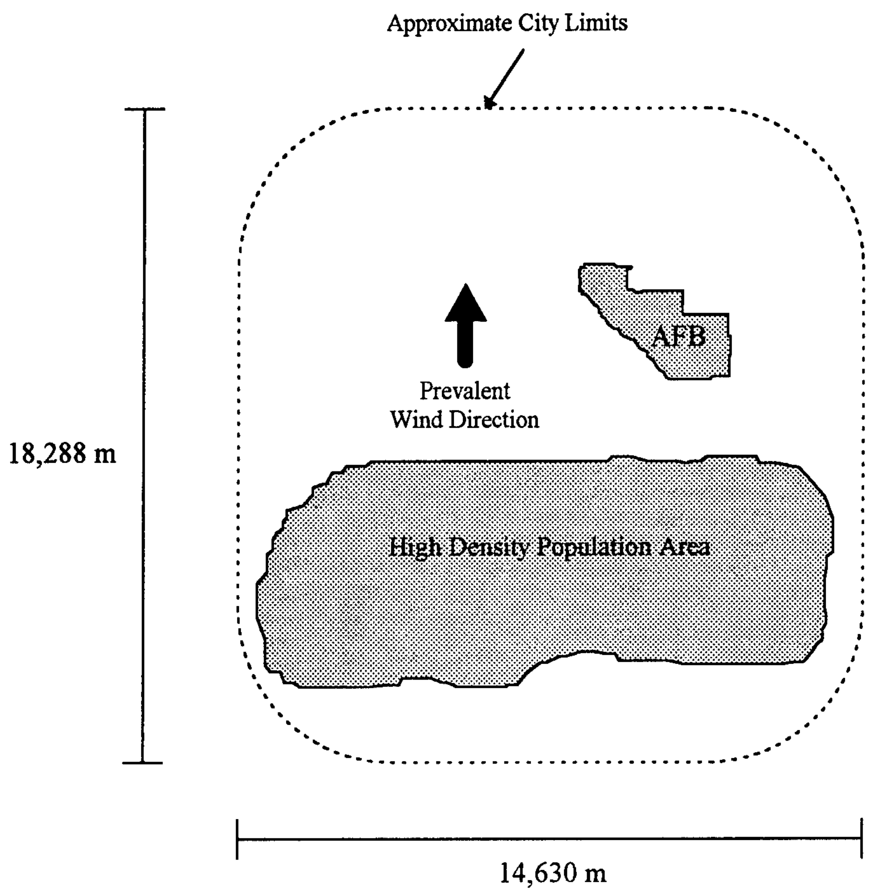

Figure 6.1: Approximate Geographical Area for Analysis

STEP 3 -- ACTIVITIES TO EVALUATE

Step 3 requires the identification of past, present, and reasonably foreseeable future actions (RFFAs). The 8-Step Conservative Determination Method for RFFAs proposed by Rumrill and Canter (1997) (see Figure 6.2) was applied to the determination of RFFAs. The Method was based upon an analysis of the principles included in over 40 U.S. court cases related to RFFAs. Step 1 of the RFFA method, the determination of boundaries, overlaps with Step 2 of the overall method utilized herein. The initial boundary determinations were made prior to addressing activities (past, present, and RFFAs), however, adjustments were made due to identified data gaps resulting from information gained in this portion of the analysis.

Past and present activities were considered to be incorporated into the existing air quality determination (Step 4 in Table 6.1). Activities addressed included: major, permitted, sources; natural gas combustion from non-permitted (including household) furnaces and boilers; road vehicle use; non-road vehicle use (e.g., aircraft, lawnmowers, etc.); and fugitive emission from solvents, adhesives, paint, waxes, etc.

The RFFA determination steps outline an evaluation process for rational inclusion and exclusion decisions regarding future activities. It is not meant to restrict the assessor from gathering data relative to a specific step prior to the completion of all previous steps. In this case, the requirement for identifying formal proposals within the subject agency (Step 2 in Figure 6.2) was satisfied by review of the capital improvements program section of the AFB comprehensive development plan (CDP). This AFB plan provided information on over 200 formal and informal development activities from 1996 to 2004. Informal projects were identified with the phrase "project not scoped." The proposals included in this plan were

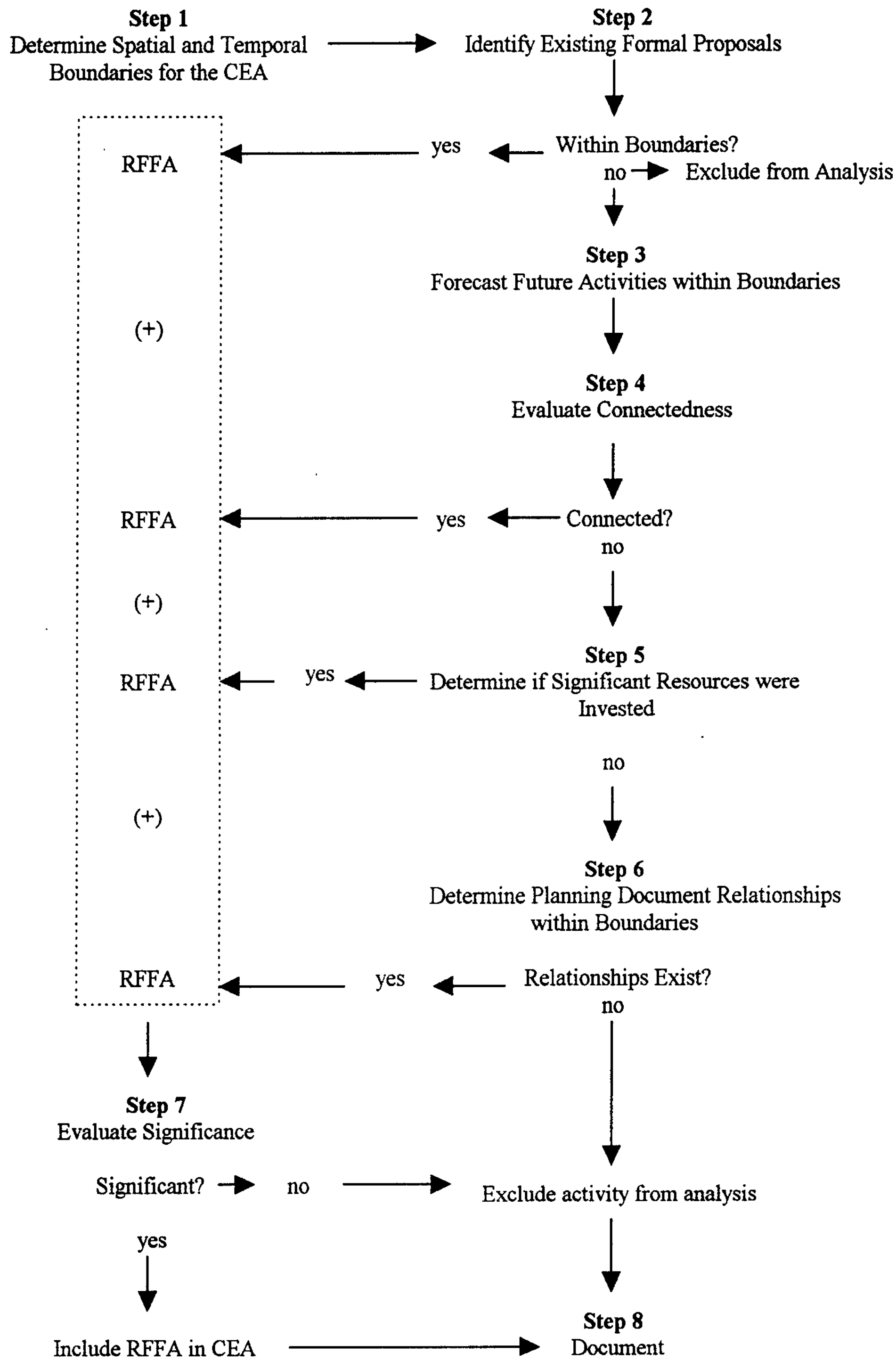

Figure 6.2: 8-Step RFFA Determination Method (Rumrill and Canter, 1997)

limited to those with an estimated construction cost of $75,000 or greater. Smaller projects activities are typically not projected beyond one year. However, several of the projects that are included in the CDP would qualify for categorical exclusion under the environmental impact assessment (EIA) process. Due to the apparent comprehensive effort by others in including future actions in the capital improvements program, no further efforts were made herein to identify AFB proposals.

The city planning office was contacted to determine what, if any, future actions were planned. It was found that the city did not have a comprehensive development plan, however, other planning documents were available. The city had a current version of a transportation development plan which included over 100 transportation-related development projects over a 20 year period from 1995 to 2015. Additionally, the city planning office was able to provide a growth trends study showing the historical population and housing trends from 1985 to 1995. These trends were used to forecast future population estimates and housing requirements. Table 6.2 presents the method used to project future populations and housing requirements. The housing requirement projections resulted in annual informal housing subdivision construction projects necessary to meet the anticipated need. Interviews with the city planning staff revealed that no other major government or private development projects were anticipated over the duration of the study time frame.

The resultant list of approximately 300 "future projects" (200 AFB projects and 100 city projects) was evaluated through application of Steps 4 through 8 of the RFFA determination method in Figure 6.2. The evaluation of AFB informal proposals and city formal and informal proposals for Steps 4 through 6 was relatively simple. All AFB informal proposals were identified within existing development program categories (e.g.,

Table 6.2: Sample Calculations for Population and Dwelling Unit Projections

1. Project Future Populations

From city growth trends report:

Year	Population
1980	94,201
1990	96,259
1996	102,790

Report shows that the city has experienced steady population increases from 1990 to 1996 with no period of decline.

Average annual increase (1990-1996) = (102,790 - 96,259)/6 ≅ 1088 people/yr

Assuming trend continues...

Year		Population
1997	102,790 + 1088 =	103,878
1998	103,878 + 1088 =	104,966
1999	104,966 + 1088 =	106,054
⋮	⋮ ⋮	⋮
⋮	⋮ ⋮	⋮

2. Project Future Dwelling Unit Volumes

From city growth trends report:

- Net change in city dwelling units for 1985 to 1995 = +1,408
- 1996 total city dwelling units = 41,259

Average annual dwelling unit increase = 1408/10 ≅ 141 units/yr

Assuming trend continues...

Year		Dwelling Units
1997	41,259 + 141 =	41,400
1998	41,400 + 141 =	41,541
1999	41,541 + 141 =	41,682
⋮	⋮ ⋮	⋮
⋮	⋮ ⋮	⋮

pavement improvement plan projects), therefore, connections were easily identified. City formal proposals were identified in goal-oriented planning documents applicable within the defined boundaries, and informal proposals were developed from the planning document trend projections. From this list, in Step 7 of Figure 6.2, a total of 145 RFFAs were identified where air emissions were expected and could be estimated and quantified. However, the original list of 300 future projects could be used when considering other media (water, soil, socio-economics, etc.) effects within a complete CEA.

STEP 4 -- BASELINE AMBIENT AIR QUALITY DETERMINATIONS

Step 4 of the CAQEA method (Table 6.1) involves the determination of baseline ambient air quality and the identification of applicable standards. From the U.S. Environmental Protection Agency (USEPA) Aerometric Information Retrieval System (AIRS), it was determined that the study area was represented by one PM_{10} monitoring station with an annual average concentration of 19 $\mu g/m^3$. The area is considered to be in attainment for all criteria pollutants; however, observed data was not available for the other pollutants. Air quality information can also be obtained from the USEPA regional office with jurisdiction over the study area. Lack of ambient monitoring data is a situation common to several areas across the United States; nonetheless, information can be obtained, or developed, to represent (or be indicative of) current conditions. One approach is to conduct a complete emissions inventory for the area determined by the spatial boundaries. Once the emission inventory for the area is complete, either the inventory itself can be used as the baseline for comparing future events to current conditions, or modeling tools can be employed to estimate the ambient concentrations. Methods for the development of the

emission inventory for the current conditions, as well as future activities, are presented in the discussion of Step 5.

STEP 5 -- EMISSION ESTIMATES

Step 5 is focused on the development of quantitative and qualitative emissions estimates for the activities included in the analysis. To present a cumulative perspective, the operational effect of these actions must be included as well as the construction phase effects. Additionally, these effects should be presented in context with other activities in the area that produce measurable air quality effects.

For this example, the emissions estimates, both for the initial existing conditions and for the future year projections, were segregated into construction and operational activities for both the city and the AFB. Emission estimates were compiled for five pollutants: carbon monoxide (CO), volatile organic compounds (VOCs), oxides of nitrogen (NO_x), sulfur oxides (SO_x), and particulates (PM_{10}). VOCs estimates were compiled as an ozone (O_3) indicator, while particulate lead was omitted due to its low level of concern within the subject area. Emissions from stationary sources were estimated using information found in *Compilation of Air Pollution Emission Factors (AP-42), Volume I, Stationary, Point, and Area Sources* (USEPA, 1995) and *Supplement B to Compilation of Air Pollution Emission Factors (AP-42), Volume I, Stationary, Point, and Area Sources* (USEPA, 1996). Following the presentation of the developed emission inventory summaries, the remaining sub-sections under Step 5 provide examples of emission-related information on various source categories.

Annual Summaries

Once the emissions estimates were developed for the operational and construction activities within the spatial and temporal boundaries, the cumulative emission estimates were organized into chronological sequence. Annual summary periods were selected based on the level of detail of information provided. Project proposal information collected was categorized by either calendar or fiscal year. For calendar year (CY) based proposals, it was assumed that all construction emissions could be applied to the CY in which the project was scheduled. Operational emissions resulting from those proposals were applied in the year immediately following the construction year and every year thereafter for the remainder of the study period. Fiscal year projections are linked to budgetary allotments. The U.S. federal government fiscal year (FY) begins on October 1 and ends on September 30. For example, FY98 begins October 1, 1997 and runs through September 30, 1998. Typically, funding for projects is not released to AFBs until the second quarter of the FY (e.g., January - March 1998). Due to time requirements for bid solicitation, contract award, and material delivery and staging, construction emissions resulting from FY projected proposals were applied to the CY after the FY (e.g., FY97 project construction emissions in CY98). The resulting operational emissions would be applied in the same manner as for CY proposals.

Table 6.3 presents a sample annual summary (1996) for the study area. The key contributors to the emission levels resulting from city activities include operational activities such as on-road vehicle use, stationary source industrial emissions, and off-road small engine operations. The key AFB operational activities include aircraft operations, on-road vehicle use, and stationary source operations. For both the city and the AFB, the primary construction activity emission source was pavement construction.

Table 6.3: 1996 Emissions Summary in the Defined Spatial Boundaries

	CO (lbs)	VOC (lbs)	NOx (lbs)	SOx (lbs)	PM10(lbs)
AFB Operation Sources					
Vehicles	694625	73682	60142	0	49146
T-37 Trim	8707	1106	179	88	32
T-37 LTO	536585	53459	18974	7397	1522
T-37 T&G	1071909	24338	77796	25268	402
T-38/AT-38 Trim	28877	4046	625	328	6
T-38/AT-38 LTO	2269369	329192	43603	23483	401
T-38/AT-38 T&G	2429602	131333	158250	69680	918
Emission Inventory	53614	162044	66252	25571	19135
4-Stroke Engines	54245	4837	616	74	88
Residential NG Use	4288	1179	10076	64	1198
Sub-Total (lbs)	**7151821**	**785216**	**436513**	**151953**	**72848**
AFB Construction Sources					
Water System	1910	145	548	50	153
Electrical System	6112	464	1752	160	488
New Construction	1070	81	307	28	85
Pavements	76591	15057	21955	2005	6115
Roofing	0	3136	0	0	0
Sub-Total (lbs)	**85683**	**18883**	**24562**	**2243**	**6841**
AFB Total (tons)	**3619**	**402**	**231**	**77**	**40**
City Operations Sources					
Vehicles	16631138	1468533	1958044	0	1910072
Commuter Aircraft	15438	18976	2821	430	1017
Emission Summary	3000687	485947	12650020	1482456	418526
4-Stroke Engines	1737643	154932	19742	2365	2820
Comm/Consum VOC	0	1613803	0	0	0
Comm/Res NG Use	128750	43750	492500	3000	58975
Sub-Total (lbs)	**21513656**	**3785941**	**15123127**	**1488251**	**2391410**
City Construction Sources					
Pavements	109061	78644	31262	2855	8708
Sub-Total (lbs)	**109061**	**78644**	**31262**	**2855**	**8708**
City Total (tons)	**10811**	**1932**	**7577**	**746**	**1200**
Entire Study Area Total (tons)	**14430**	**2334**	**7808**	**823**	**1240**

Operational Activities -- Major Sources

Development of the cumulative emission estimate began with the current stationary source emission inventory for the AFB. Incorporation of this existing document saves time and provides information on specific activities that may be useful as surrogate data for future activity emissions. The emission inventory for an AFB can be obtained from the air quality manager in the base environmental compliance office.

Major stationary source emissions for the city, or other federal facility, activities may be obtained either through the state air quality office or through the USEPA regional office. Depending on the level of detail requested on individual sources it may be necessary to process a Freedom of Information Act (FOIA) request. Some states, however, maintain a separate document, or data file, containing summary emission data for each major source. This document, if available, can be obtained without a FOIA request. The state summary document used for this study provided both the actual and allowed emissions for each source and pollutant, and included sources where emission inventories had not been completed (TNRCC, 1997). Where no emission inventory had been completed and only the allowed emissions were reported, these allowed emissions were used in the development of the cumulative inventory. Also, the state summary only provided the most current data available. For example, if one source reported actual emissions for 1994, 1995, and 1996 and another for 1993 only, the summary report provided the 1996 emissions from the first source combined with the 1993 emissions from the second source. While this data may be inaccurate as to current emissions, it was the best information available.

Operational Activities -- Vehicles

One of the largest air emission source categories in the study area is vehicle operations. Since vehicles are mobile sources, they are not included in stationary source emission inventories; therefore, separate estimates were developed. Factors for calculating CO, VOC, NOx, and PM_{10} emissions are available in the *Compilation of Air Pollution Emission Factors (AP-42), Volume II: Mobile Sources* (USEPA, 1985) and *Supplement A to Compilation of Air Pollution Emission Factors (AP-42), Volume II: Mobile Sources* (USEPA, 1991b). These emission factors are based on vehicle type and number of vehicle miles traveled (VMT). To calculate the emissions for the vehicle use in a given area for a specific time period, the information requirements are: the VMT for the period of concern; the type and age of vehicles used; and the fraction of the VMT that can be attributed to each vehicle type. AP-42 provides emission factor information for eight different vehicle types of various ages with multiple adjustment factors for such considerations as: percent cold start versus hot start; temperature and altitude variations; average speed; and potential for improper fuel use. Additionally, the road surface itself can be considered as a source for fugitive dust emissions resulting from vehicle traffic. PM_{10} estimations can be developed for fugitive dust from both paved and unpaved road surfaces based on data and methods provided in AP-42.

For this example, VMT and number of vehicles for the entire county (excluding the AFB) was obtained from the state Department of Transportation. No information was available regarding vehicle type and age. Population figures for the county and city from the growth trend report were used to determine the number of vehicles in the city by ratio to the

city population. The national average age and type tables and emission sensitivity tables provided in AP-42 were used due to the lack of specific vehicle fleet mix data.

If the VMT is not readily available for the study area, such as for the AFB, it can be determined via an area traffic study. Traffic studies can typically be obtained from the AFB or city traffic engineer or planner for the relevant areas. In this example, a traffic study was identified for use in developing a VMT estimate for the AFB. As discussed in Beaton et al. (1982), traffic counts at each roadway section of concern can be multiplied by the length of the roadway segment to determine the VMT for that segment. Adding the VMT for each segment provides the VMT data for the total area needed for the previously discussed calculations (USEPA, 1991a).

Operational Activities -- Aircraft

Aircraft emissions are an important component of the emissions inventory when there is major air traffic such as for an AFB with an active flight line or a city with a commercial airport. AP-42 provides emission factors for several aircraft types, however, the military listings are incomplete. Additional emission factor information for military aircraft can be found in *Calculation Methods for Criteria Air Pollutant Emission Inventories* by Jagielski and O'Brien (1994). One important consideration when developing the estimates is that aircraft engine maintenance and testing operations need to be included where appropriate. For this example, the municipal airport is not a major hub and little if any maintenance is performed. For those aircraft activities only the landing-and-takeoff (LTO) cycles are included as mobile source contributions.

The AFB, however, conducts routine testing and maintenance of the aircraft operating from its flightline. Some of these activities, such as aerospace ground equipment (AGE) emissions and jet engine test cell emissions, were included in the base emissions inventory and, therefore, did not require separate calculations. An additional maintenance activity that is not accounted for in the base emission inventory is the conduction of aircraft trim operations where the engine power output levels are evaluated while the aircraft is held stationary. This activity differs from jet engine test cell operations in that the engine is not removed from the airframe. Aircraft maintenance personnel can be contacted to obtain trim operation statistics.

The calculation of LTOs for military aircraft is conducted in the same manner as for civilian aircraft with the appropriate emission factors and operating times for each specific engine. Additionally, Air Force training activities can include considerable emissions from touch-and-go (T&G) activities. Information such as the type and number of aircraft used at the AFB, the number of LTO and T&G operations conducted annually by each aircraft type, and the percentage of training versus operational sorties flown was obtained from the base operations flight.

Construction Activities -- Source Categories

Typically, a NEPA analysis deals with the emissions resulting from new activities. These emissions are evaluated for both the construction and operation stages of a project and, occasionally, for the demolition stage. In a cumulative sense, construction, operation, and demolition phase emissions should be included for all activities within the spatial and temporal boundaries. The previously discussed operational emission estimates provide the

operational stage emissions for the activities initiated prior to the study timeframe (e.g., the baseline emissions). The categories of projects evaluated include: water systems, sanitary sewer systems, storm drains, NG distribution systems, electrical distribution systems, facility disposals, pavements construction and repair, facility construction, roofing construction and repair, and housing development.

Construction Activities -- Pavements

Paving activities identified within the spatial and temporal boundaries included: asphalt or concrete pavement construction and repair, and runway striping. Striping emission estimates can be made through a simple estimation of the volume of paint used multiplied by the paint-specific VOC emission factors provided in AP-42. Concrete construction (entire existing roadway demolished and re-built) was estimated with the per-acre emission factors for fugitive dust and combustion sources as described for general construction activities. Concrete repair projects, identified where the entire roadway was not to be demolished and re-built, were estimated similar to the concrete construction projects except that the assumption was made that only 25% of the roadway would be demolished and rebuilt. The reasoning for this assumption was that if more than 25% of a road segment (e.g., paved area between two intersections) had failed, that segment would be identified for a complete re-build.

Asphalt paving projects were also segregated into repair and complete re-construction. If a road segment was to be repaired, emission estimates were based on the application of the asphalt overlay. For complete re-builds, asphalt emissions were combined

with combustion emissions as described for concrete construction (AP-42 includes a section -- Section 4.5 -- on estimating emissions from asphalt paving operations).

The primary emissions from asphalt pavements are VOCs. Liquefied asphalts are used in tack-and seal operation, roadbed priming for hot-mix asphalt concrete application, and as the primary binder for small paving operations. Large paving activities typically rely on hot-mix asphalt concrete which is created by heating asphalt cement and combining it with the aggregate (USEPA, 1995).

For this study, it was determined that hot-mix asphalt concrete was to be used for all AFB applications. Further, since the AFB and the city use the same local area pavement contractor, the assumption was made that asphalt emulsions would also be used for city projects. AP-42 emission factors are available for estimating long-term emissions from cutback asphalt applications. AP-42 does not, however, provide emission factor information regarding asphalt emulsion emissions. Emulsified asphalts consist of asphalt cement suspended in water containing an emulsifier. Based on information in Markwordt and Bunyard (1977), the lb/lb emission factors presented in AP-42 for cutback asphalt were modified for asphalt emulsions.

STEP 6 -- DETERMINING THE CHANGE IN AIR QUALITY

Once the cumulative emissions had been estimated and summarized within the pre-determined boundaries, the change to the background conditions should be evaluated. There are two main options for the "change in air quality" analysis: evaluation of emission levels, and evaluation of ambient concentrations. Both options were used in this example;

however, individual preference and the availability of background data could influence the choice.

Emission Levels

Given the emissions estimates from Step 5, the most expedient analysis approach is to evaluate the emission level changes anticipated from the proposed activities in the study area. Parameters that can be obtained from this level of analysis include comparisons of the AFB emissions with and without the proposals and comparison of the total area emissions with and without the proposed AFB activities. Figures 6.3 and 6.4 graphically present these comparisons for PM_{10} over the 10 year temporal boundaries for the study. PM_{10} was selected for presentation since ambient monitoring station data was available allowing for direct comparison of the emission level analysis to the ambient concentration level analysis. Separate graphs were generated to display the emission changes within the AFB boundaries and to display the effect of these activities on the total study area. The focus of a NEPA analysis is on federal activity effects, not private, local, or state activity effects. The information is presented in this format to emphasize the federal influence. If desired, the analysis focus can be easily shifted to present the effects on the area from alternate viewpoints such as city or state government influence.

Careful inspection of Figures 6.3 and 6.4 shows that the largest effects occur in 1997 and 2001. However, it is important to interpret this information in context with the availability of information for any given year. In the later years of the study period, the emission effects of the proposed activities appears to taper off. By 2005, the emissions appear to return to almost the same level as was predicted in the absence of the AFB

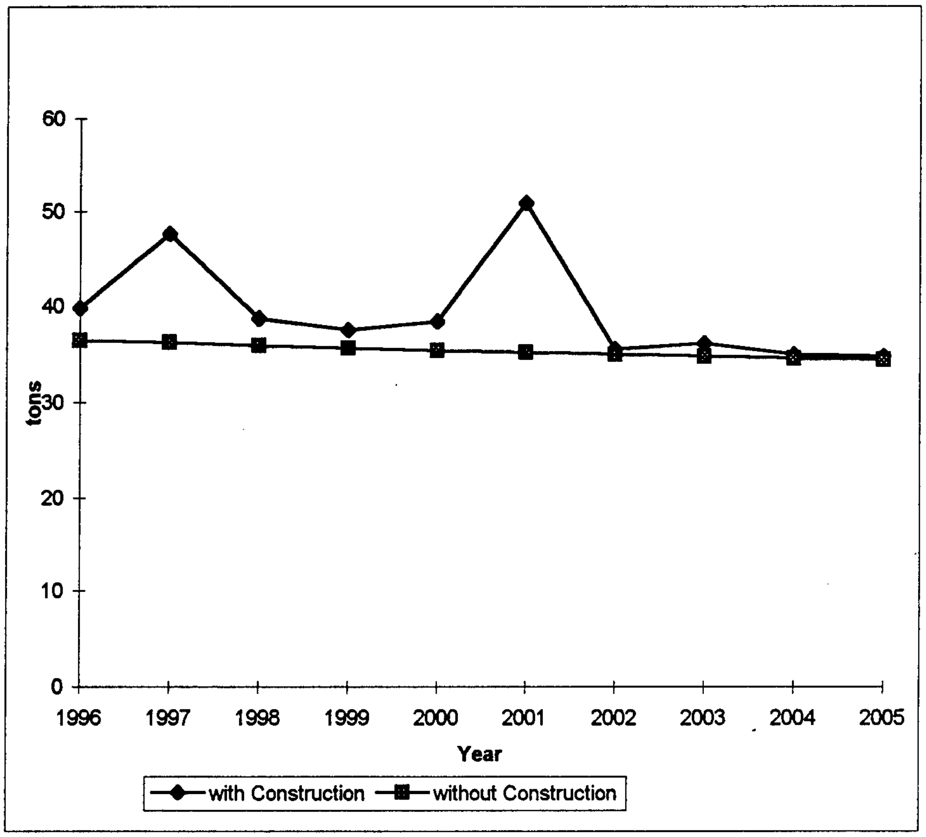

Figure 6.3: AFB PM10 Emissions Comparisons

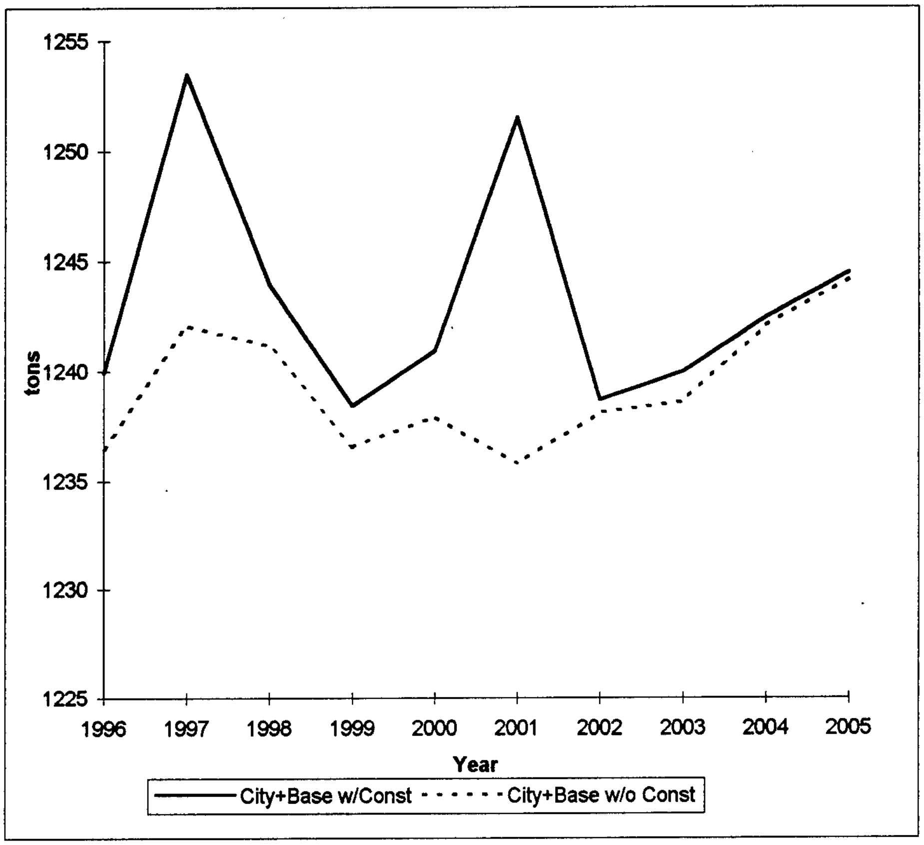

Figure 6.4: AFB Project Effect on PM10 Emissions in the Study Area

projects' influence. Three points can be made with regard to this observation. First, while AFB development activities will exert a short term influence on the specific AFB and study area emissions, the long term, operational phase influence of those activities is minimal. Second, since the majority of the PM_{10} emissions increments identified in this example are caused by the construction activity, not the operation of the proposed facility, it would be appropriate to focus PM_{10} mitigation efforts on the construction processes. This does not mean that the construction phase will be of primary importance for mitigation consideration in every example. The value is in the ability of the assessment tool to identify the appropriate focus. And third, it is unlikely that AFB development activities will simply end by the year 2005. A more reasonable explanation is that development proposals for the later years of this study and beyond have not yet, even informally, been formulated. Were this study to be re-evaluated at a later time, it is likely that additional RFFAs would be available for inclusion that would elevate the development activity construction emissions for the time period of 2002 through 2005 to those similar to the first four to five years of the study period.

The graphical analysis such as shown in Figures 6.3 and 6.4 can be used to present the cumulative effect of AFB development activity for individual pollutants. While this is valuable, the analysis can be enriched. A tabular presentation of the percentage increase in emission level, relative to each pollutant and year, can provide additional insight into effect significance and proper mitigation focus. Table 6.4 presents the percent increase in the emission level of each pollutant, annually, throughout the study timeframe within the AFB boundaries. Table 6.5 presents the same type of data for the AFB influence with respect to the total study area emissions.

Table 6.4: AFB Proposal Effects on AFB Emissions

Year	Pollutants (%)*				
	CO	VOC	NOx	SOx	PM10
1996	1.20	2.40	5.63	1.48	9.39
1997	3.64	3.02	17.46	4.49	31.47
1998	0.89	1.28	4.50	1.08	7.83
1999	0.58	1.64	3.09	0.70	5.23
2000	0.95	1.47	4.89	1.15	8.57
2001	5.09	4.34	24.65	6.14	44.74
2002	0.25	0.21	1.26	0.18	1.71
2003	0.50	0.38	2.43	0.47	3.88
2004	0.15	0.15	1.13	0.05	1.07
2005	0.12	0.14	1.03	0.02	0.87

*All percentages are increases in the emission levels over the 1996 emission levels (the base year chosen for this analysis without considering construction projects on the AFB)

Table 6.5: AFB Proposal Effects on Total Study Area Emissions

Year	Pollutants (%)*				
	CO	VOC	NOx	SOx	PM10
1996	0.40	0.49	0.16	0.15	0.29
1997	1.35	0.68	0.54	0.50	0.95
1998	0.34	0.29	0.14	0.12	0.23
1999	0.23	0.37	0.10	0.08	0.16
2000	0.38	0.34	0.15	0.13	0.25
2001	2.04	0.99	0.76	0.68	1.31
2002	0.10	0.05	0.04	0.02	0.05
2003	0.20	0.09	0.07	0.05	0.11
2004	0.06	0.03	0.03	0.01	0.03
2005	0.05	0.03	0.03	0.00	0.02

*All percentages are increases in the emission levels over the 1996 emission levels (the base year chosen for this analysis without considering construction projects on the AFB)

The graphical analysis revealed that 2001 was one of the years with the most extreme effect for PM_{10} emissions. Table 6.4 shows that, within the year 2001, AFB CO emissions increase 5.09%, VOC emissions increase 4.34%, NO_x emissions increase 24.65%, SO_x emissions increase 6.14%, and PM_{10} emissions increase 44.74%. This indicates that the primary areas of concern for the AFB, with regard to its local air quality, would be to focus its mitigation efforts on both NO_x and PM_{10} emissions. However, when addressing the AFB influence on total study area emissions, the focus of concern shifts. Table 6.5 indicates that the 2001 AFB proposal emissions result in a 2.04% increase in CO, a 0.99% increase in VOC, a 0.76% increase in NO_x, a 0.68% increase in SO_x, and a 1.31% increase in PM_{10} emissions. From the total study area viewpoint, the primary pollutant of concern is CO. This demonstrates the importance of evaluating an activity's effect, not just on its immediate surroundings, but also with respect to the total study area setting.

Additionally, the evaluation of cumulative emissions can provide insight into more complex atmospheric issues such as acid deposition and photochemical oxidant formation. For example, several studies have indicated that sulfur oxides and nitrogen oxides are the principal precursors to acid deposition (Canter, 1997). Evaluation of the change in emission levels of these two pollutants within the study area, therefore, provides inferences as to the future potential for acid precipitation.

A qualitative relationship between the major chemical and atmospheric variables active in photochemical oxidant formation, which includes urban (tropospheric) ozone, can be expressed as (Cooper and Alley, 1994):

$$PPL = \frac{(ROG)(NO_x)(\text{Light Intensity})(\text{Temperature})}{(\text{Wind Velocity})(\text{Inversion Height})}$$

where,

PPL = photochemical pollution level

ROG = concentration of reactive organic gases (to include VOCs)
NO_x = concentration of oxides of nitrogen.

It is readily apparent from this qualitative model that increases in NO_x and VOC emissions have strong potential to increase tropospheric ozone concentrations. Further, evaluation of the VOC/NO_x ratio assists in focusing mitigation efforts (Wolff, 1993). When this ratio results in a value less than ten (VOC/NO_x < 10), the condition is called VOC limiting. When the ratio is greater than twenty (VOC/NO_x > 20), the condition is called NO_x limiting. The optimal mitigation strategy for prevention or reduction of tropospheric ozone is to focus emission control efforts on the pollutant termed as the limiting factor. For this example, the ratio indicates that the study area condition is VOC limiting for all years addressed at both AFB and study area scales.

Ambient Concentrations

While an evaluation of changes in emission levels yields useful information, it does not provide the assessor with an estimate of when, or if, ambient air quality standards (AAQS) will be exceeded. In order to determine the change to the ambient concentration resulting from proposed activities, it is necessary to have observations or estimations of existing ambient concentrations. Ambient air quality monitoring data was collected for the study area in conjunction with Step 4; however, data were available only for PM_{10}. Since only one PM_{10} monitoring station was located within the study area, the average annual concentrations reported for this location were used as the average ambient concentration for the entire study area. It is not surprising, or uncommon, to find that ambient air quality monitoring data is less than complete for an area requiring NEPA analysis.

As proposed by Rumrill and Canter (1998a), cumulative air quality effects can be quantified and analyzed with the assistance of simple techniques such as rollback, simple area source, and box models. The available data was compared to the input requirements of each model type, and it was determined that the box model was the most appropriate for the data collected for this example. No implication is intended as to the suitability of the other two model types for cumulative assessments. Other studies may find one of the others to be more suitable.

Multiple equations are available for box modeling. For example, Gifford and Hanna demonstrated the utility of box model application to long term urban air quality analysis as follows (Benarie, 1980):

$$X = \mathrm{c}\,\frac{Q}{A\bar{u}}$$

where,

X = the ambient concentration ($\mu g/m^3$)
Q = the total area emissions (μg/sec)
A = the area (m^2)
$\bar{u}$ = the annual average wind speed (m/sec), and
c = a correction factor applied in a model calibration exercise

The correction factor is needed to account for inherent assumption errors. Box models assume that the pollutant emissions are uniformly mixed in the entire volume of air. While some mixing will occur, factors such as the location of emission sources (e.g., ground level) cause the actual pollutant distribution to be non-uniform with the highest concentrations near the emission sources.

The desired comparison in ambient air quality modeling is to relate the predicted concentrations to the observed values from monitoring stations. Monitoring stations are

typically located so that the average pollutant concentration respirated by the human population can be determined. In other words, monitoring stations tend to be located near ground level emission sources. Placement heights required by the USEPA for CO, O_3, NO_2, SO_2, and PM_{10} monitoring stations range from 2 to 15 meters above ground level (USEPA, 1991a).

Gifford and Hanna demonstrated their application of the box model in 29 major urban areas for both SO_2 and particulate matter to determine annual average concentrations (Benarie, 1980). Using ambient air quality monitoring data for calibration, they found that an average correction factor of 50 should be applied for SO_2 and 202 for particulates. The reason given for the difference in the correction factor between the two pollutants was that the sulfur dioxide emissions accounted for in the respective inventories included a large fraction associated with tall stacks (Benarie, 1980). Emissions from these tall stacks would disperse differently than emissions from ground level sources and therefore, this would reflect on the concentrations observed at the monitoring stations. The correction factors obtained for each city varied for particulates from a low of 57 to over 600. Similar variation was found in correction factors for sulfur dioxide. These box model applications were all applied to large urban centers. Finally, in a related study, Wu found that, for small urban areas, an average particulate matter correction factor of 892 was more appropriate (Benarie, 1980).

This current study was performed on an urban area (population in the range of 100,000) that can easily be categorized as small. Table 6.6 presents the 1996 annual average concentrations calculated for PM_{10} with the influence of the proposed base activities using the same form of the box model as Gifford and Hanna. Table 6.7 presents the

Table 6.6: Uncalibrated Gifford and Hanna Box Model Calculations

<u>Available Information</u>

1996 Total PM_{10} Emissions = 2,479,807 lbs/yr (from Table 6.3)
Local Annual Average Wind Speed = 5.66 m/s (from local weather data)
City Plus AFB Area Dimension - x (windward) = 18,288 m
- y (crosswind) = 14,630 m

Using the uncorrected equation:

$$X = \frac{Q}{A\bar{u}}$$

2,479,807 lbs/yr = 35,661,752 μg/s

X = (35,661,752)/(18,288 x 14,630 x 5.66) = 0.02355 μg/m^3

Using the uncorrected equation:

$$X = c\frac{Q}{A\bar{u}}$$

c = 202 (based on study of 29 urban areas, many of which were larger than the urban area in this example

X = (202)(0.02355) = 4.56 μg/m^3

Table 6.7: Calibrated Box Model Results for PM_{10}

Using the equation:

$$X = c\frac{Q}{A\bar{u}}$$

Set $X = 19\ \mu g/m^3$

Solving the equation for c with the 1996 data (0.02355 $\mu g/m^3$ from Table 6.6):

$$c = 806.8 \cong 807$$

Applying this equation with the correction factor to the projected PM_{10} emissions throughout the study period yields the following results:

Year	Projected Ambient Concentration With Proposed AFB Activities ($\mu g/m^3$)	Projected Ambient Concentration Without Proposed AFB Activities ($\mu g/m^3$)	Increase ($\mu g/m^3$)
1996	19.00	18.95	0.05
1997	19.21	19.04	0.17
1998	19.07	19.02	0.05
1999	18.98	18.95	0.03
2000	19.02	18.97	0.05
2001	19.18	18.94	0.24
2002	18.99	18.98	0.01
2003	19.01	18.98	0.03
2004	19.04	19.04	0.00
2005	19.07	19.07	0.00

calculations for the determination of an appropriate correction factor for this study and its application to future emission projections. The correction factor determined here (807) compares well to the average for small urban sources (892) developed by Wu (Benarie, 1980) assuming that the proportion of PM_{10} in particulate matter remains relatively constant over the analysis. The largest annual PM_{10} increase over the 10 year period is 0.24 $\mu g/m^3$.

The analysis of air quality effects resulting from federal activities is often required in areas where ambient air quality monitoring data is not available. In such cases, the average correction factors for the appropriate urban center size, as determined by Gifford and Hanna, and later by Wu, could be applied. These values are, however, averages. Application of an average value to a specific situation introduces the additional error of the degree of difference between the application site and average conditions. However, this approach can provide the assessor with a sense of the "order of magnitude" of relative change on ambient air quality resulting from the proposed activities. On the other hand, the predicted values should not be accepted as truly representative of the actual future concentrations. The average correction factors should only be used to determine the trend (e.g., increasing, decreasing, stable) in the ambient concentration resulting from the proposed activities.

Although not addressed in this example, this modeling procedure can also be applied to the evaluation of long-range transport effects. Downwind transport determinations should be made where there is some considerable effect on ambient air quality, or where concern is expressed over pollutant transport to a new location. To evaluate this effect, the study area can be modified to include the downwind receptor location, and the ambient concentrations can be recalculated using only the source emission contributions from the original study area

as shown in Figure 6.5. This will not provide the assessor with an accurate prediction of the actual ambient concentration at the downwind area. It will; however, allow the determination of the study area's contribution to the overall air quality in the downwind area. With ambient data obtained relative to this new receptor, the percentage contribution resulting from the study area activities can be determined.

STEP 7 -- SIGNIFICANCE DETERMINATION

The significance of these predicted cumulative air quality effects can be interpreted via the multi-criteria decision making method developed by Rumrill and Canter (1998c). Recommendations for rating factor intensities are shown in Table 6.8. Based on these recommendations, Table 6.9 presents the intensity ratings for the data collected and developed in this example relative to AFB level PM_{10} emissions. Table 6.10 presents the factor weights and matrix calculations to determine the "weighted effect" significance score for PM_{10} relative to the AFB boundaries. Table 6.11 presents the "weighted effects" for each pollutant and boundary condition (AFB and total study area) to demonstrate the change in significance based on perspective.

From Table 6.11, it can be concluded that the cumulative air quality effects are not significant. Standard practices for limiting air pollutant emissions were identified in the emissions calculation portion of the assessment (Step 5). Calculations were based on the assumption that these measures would be employed. However, the significance determinations were made with the assumption that no further mitigation efforts would be applied to the predicted emissions.

The significance rating matrix (Tables 6.8 and 6.10) was designed generically for widespread application. For this particular application, some data was not available. For

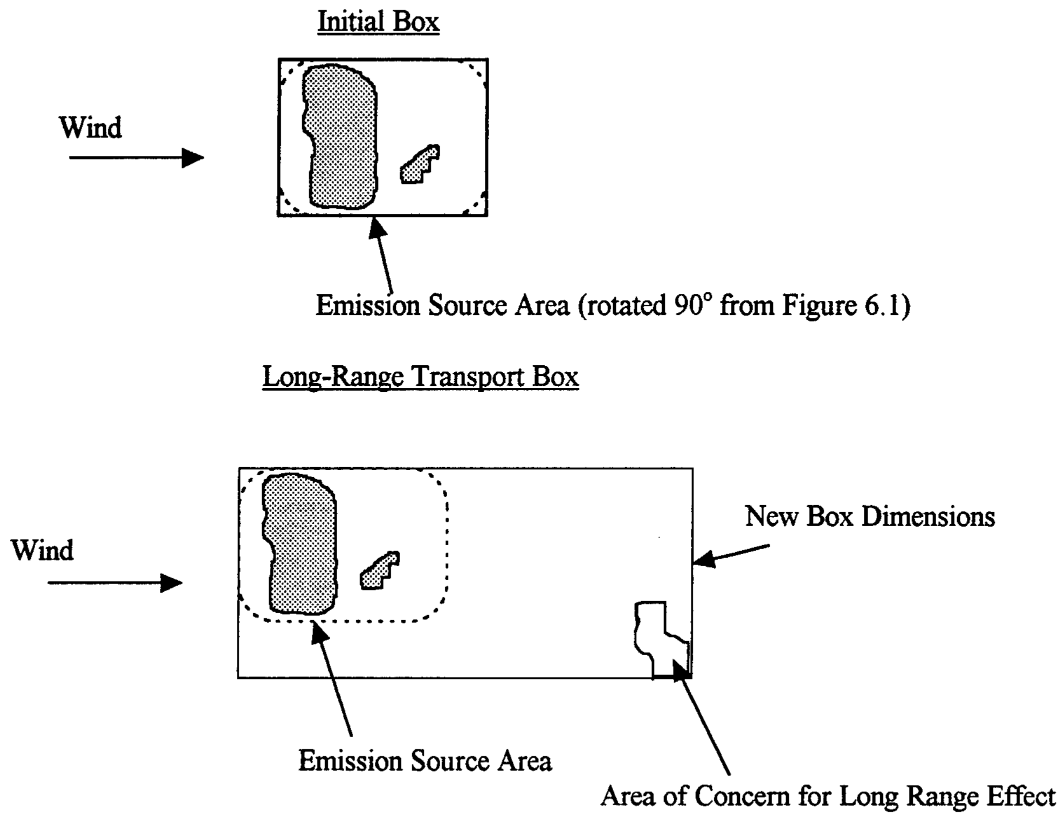

Figure 6.5: Long Range Pollutant Transport Analysis

Table 6.8: Factor Intensity Ratings for Cumulative Air Quality Effects

Factor	Cumulative Intensity High (3)	Moderate (2)	Low (1)
Pollutant Emissions			
- % change in emission level	10% or greater increase	5 - 9% increase	< 5% increase
- timing, duration, and rate of change	occurs early in study period, > 5 years duration, high rate of increase	occurs midway through study period, 1 - 5 years duration, moderate rate of increase	occurs late in study period, < 1 year duration, slow rate of increase
- comparison to emission limitations (% noncompliance)	10% or greater	5 - 9%	< 5%
Ambient Air Quality Standards			
- change in ambient concentration	> 5% increase	1 - 5% increase	< 1% increase
- timing, duration, and rate of change	occurs early in study period, > 5 years duration, high rate of increase	occurs midway through study period, 1 - 5 years duration, moderate rate of increase	occurs late in study period, < 1 year duration, slow rate of increase
- violation of standards	cause new violation	impairs plans to mitigate existing violation	small contribution to existing violation
- influence on air pollution episodes	new occurrence where none observed before or large increase in existing number of episodes	moderate increase in existing episode frequency or required level of response	small increase in existing episode frequency or required level of response
- influence on current area classification	exceeds classification based limits	classification based limits reached	limits future development
Public Perception			
- level of public concern	high level of concern expressed	some concern expressed	little concern expressed
Secondary/Indirect/Synergistic Effects			
- influence on PPL potential	10% or greater increase in precursor emissions	5 - 9% increase in precursor emissions	< 5% increase in precursor emissions
- influence on VOC/NO_x ratio	10% or greater increase to limiting pollutant or change of limiting pollutant	5 - 9% increase to limiting pollutant	< 5% increase to limiting pollutant
- influence on stratospheric ozone	large increase in ODC emissions	moderate increase in ODC emissions	small increase in ODC emissions
- influence on global warming	large increase in precursor emissions	moderate increase in precursor emissions	small increase in precursor emissions
- spatial (transboundary) transport	large contribution to downwind area concentration	moderate contribution to downwind area concentration	small contribution to downwind area concentration
- influence on acid deposition potential	large increase in precursor emissions	moderate increase in precursor emissions	small increase in precursor emissions
Human Health			
- level of carcinogenic effect	known human carcinogen	probable human carcinogen	possible human carcinogen
- level of non-carcinogenic effect (dose response relationships, comparison to thresholds, synergisms, etc.)	Air Toxics - concentration above MAAC (or TLV/1000) Others - high likelihood of adverse effect	Air Toxics - concentration at MAAC (or TLV/1000) Others - moderate likelihood of adverse effect	Air Toxics - measurable conc. below MAAC (or TLV/1000) Others - low but identifiable possibility of adverse effect
Mitigation			
- timing/focus of mitigation vs. timing/focus of effects	allows for long-term (>5 years) continuance of mitigable effect	allows for continuance of mitigable effect for 1 - 5 years	allows for continuance of mitigable effect for less than one year

ODC = Ozone Depleting Chemical, MAAC = Maximum Allowable Ambient Concentration, TLV = Threshold Limit Value

Note: Shift in pollutant of concern factor intensity ratings not included (addressed through separate ratings for each spatial boundary condition)

Table 6.9: Factor Intensity Ratings for AFB Level PM_{10}

Factor	Analysis Data	Cumulative Intensity Rating
<u>Pollutant Emissions</u> - % change in emission level	at least 1 year has >10% increase (44.74% highest noted in Table 6.4)	3
- timing, duration, and rate of change	Figure 6.3 shows 2 peaks of moderate increase, one early and one midway through the study, each lasts for 1 year	2
- comparison to emission limitations (% noncompliance)	all compliance limits met	0
<u>Ambient Air Quality Standards</u> - change in ambient concentration	<1% increase across study timeframe (0.24 $\mu g/m^3$ highest noted in Table 6.7)	1
- timing, duration, and rate of change	extremely slow increases observed in initial half of study period (see Table 6.7)	1
- violation of standards	no violations	0
- influence on air pollution episodes	no episodes expected	0
- influence on current area classification	no predicted limitations on development or change in classification	0
<u>Public Perception</u> - level of public concern	subject occasionally broached in meetings, small level of concern	1
<u>Secondary/Indirect/Synergistic Effects</u> - influence on PPL potential	N/A	0
- influence on VOC/NO_x ratio	N/A	0
- influence on stratospheric ozone	not an ODC	0
- influence on global warming	not a precursor	0
- spatial (transboundary) transport	small contribution to nearby downwind areas	1
- influence on acid deposition potential	not a primary precursor	0
<u>Human Health</u> - level of carcinogenic effect	not a carcinogen	0
- level of non-carcinogenic effect (dose response relationships, comparison to thresholds, synergisms, etc.)	concentration low but measurable, synergisms with sulfates could produce some effects	1
<u>Mitigation</u> - timing/focus of mitigation vs. timing/focus of effects	effect continues throughout study period (>5 years) - study assumes no additional mitigation beyond standard construction and operation practices	3

ODC = Ozone Depleting Chemical, MAAC = Maximum Allowable Ambient Concentration, TLV = Threshold Limit Value

Table 6.10: Significance Rating for AFB Level PM_{10}

Factors	Factor Weighting (a)	Cumulative Effect Intensity (b)	Weighted Effect (axb)
	High importance = 3 Medium importance = 2 Low importance = 1	Large Adverse = 3 Moderate Adverse = 2 Small Adverse = 1 No Adverse Effect or Beneficial Effect = 0	
<u>Pollutant Emissions</u>			
% change in emission level	2	3	6
timing, duration, and rate of change	2	3	6
comparison to emission limitations (% noncompliance)	2	0	0
<u>Ambient Air Quality Standards</u>			
change in ambient concentration	2	1	2
timing, duration, and rate of change	2	1	2
violation of standards	3	0	0
influence on air pollution episodes	2	0	0
influence on current area classification	2	0	0
<u>Public Perception</u>			
level of public concern	3	1	3
<u>Secondary/Indirect/Synergistic Effects</u>			
influence on PPL potential	2	0	0
influence on VOC/NO_x ratio	2	0	0
influence on stratospheric ozone	1	0	0
influence on global warming	1	0	0
spatial (transboundary) transport	2	1	2
influence on acid deposition potential	2	0	0
<u>Human Health</u>			
level of carcinogistic effect	2	0	0
level of non-carcinogistic effect	2	1	2
<u>Mitigation</u>			
timing/focus of mitigation vs. timing/focus of effects	2	3	6
			Total = 29

Note: The factor weightings are considered to be generic and are explained elsewhere (Rumrill and Canter, 1998c). The intensity ratings are from Table 6.9.

Table 6.11: Weighted Effects Comparisons for Air Quality Cumulative Effects

Pollutant	AFB	Total Study Area
CO	19	15
VOC	21	19
NO_x	29	19
SO_x	21	17
PM_{10}	29*	19

Note: Possible range of values -- 0 - 35 (low significance or nonsignificant)
36 - 72 (moderate degree of significance)
73 - 108 (high level of significance)

*Basis is shown in Table 6.10; bases for other weighted effects are available elsewhere (Rumrill, 1998).

example, in all but one case (PM_{10}), no ambient concentration information was available for use in the "Ambient Air Quality Standards" portion of the matrix. Ambient data was not available due to the lack of monitoring stations in the area. However, discussions with state environmental regulators led to the conclusion that there were no ambient concentrations of concern relative to the unmonitored pollutants (CO, VOC, NO_x, and SO_x). Comparisons of available ambient data for PM_{10} were made to the national standard (50 $\mu g/m^3$ annual average) since the state and local standards were not more restrictive. Additionally, the permit compliance status of the local industrial sources is confidential information. Since this factor cannot be interpreted as an indication of total compliance or partial noncompliance, no assessment of percentage of noncompliance with permits could be made for the total area. The AFB was determined to be in compliance with all permit limitations.

Public concern was evaluated by interviewing city and AFB personnel responsible for public meetings on development issues. The environmental office in the Civil Engineer Squadron at the AFB was contacted for public opinions on development issues, and the city planning office was contacted for public opinions on developments in the entire study area. Both offices stated that the public has expressed very little concern over air quality issues; however, the topic is occasionally broached.

STEP 8 -- MITIGATION OPPORTUNITIES

Opportunities for mitigation can be determined and evaluated by applying the method discussed in Rumrill and Canter (1998c). Since the primary influence on air quality occurs during the construction stage of the activities presented in this example, it would be appropriate to focus mitigation attention on construction procedures and construction

equipment emission control. However, since it was determined that there would be no significant effect on air quality resulting from these development activities, it may be prudent to focus additional mitigation resources on environmental resources other than air quality.

OBSERVATIONS AND CONCLUSIONS

This case study has presented an application of the authors' proposed methods (Table 6.1 and Figure 6.2) to a real world example. The intent was to validate the previously proposed methods as well as to demonstrate the practicalities of air quality CEA. This study presents the details and assumptions of each step of the analysis. Presentation in this format demonstrates the value of the assessment methods in context with their limitations in real world application.

Once this type of study has been conducted for a specified region, it can be incorporated into the formal development planning documents of both the city and the federal installation. Current practice in development planning recommends a section discussing the environmental resources of the planned area. Regarding this case study, the Air Force has included such discussions in its comprehensive development planning documents as have city planning agencies. The addition of a CEA component into these documents seems logical and desirable.

Once the CEA study is formalized, either as a section of a comprehensive plan or as a separate document, it can be referenced in project-specific environmental impact studies conducted on the included activities. These project-specific studies may lead to environmental assessments (EAs) or environmental impact statements (EISs). If new project

proposals are planned, the CEA can be easily updated to incorporate the relevant effects. When conducting the individual project assessments, the requirements for CEA can be adequately addressed by discussing only the relevant quantitative and qualitative results, their influence on significance determinations, and the additional mitigation opportunities as determined here. The net result would be a more complete NEPA document (either an EA or EIS) for the project proposal without a noticeable increase in volume.

The CAQEA study should be reviewed and updated on a time schedule appropriate to the development planning pace of the assessed area. Open communication between the federal agency planning office and the city planning office can facilitate the time schedule necessary to ensure updates are performed adequately.

In summary, this study has provided a practical example of the application of a step-wise approach for cumulative air quality effects. To that end, the following observations and conclusions can be drawn:

(1) This analysis represents only one component of an overall CEA addressing all media. It is intended to be maintained as an independent document or possibly an appendix to a community development plan. It will require periodic updates as conditions change or new information is obtained, possibly on an annual or biennial basis. And, it is envisioned that the results of this study would be incorporated by reference into each relevant EA or EIS conducted at the AFB.

(2) Assessors should not restrict themselves to following the exact order of the method steps. The step sequences are intended to guide the assessor's thought processes, not dictate the chronology of step applications. It can be useful to revisit steps as new information becomes available.

(3) Quantitative analysis results can shift the focus with respect to the pollutant of concern when the spatial or temporal context is varied.

(4) Caution should be used when applying average, or surrogate, correction factors when calibrating dispersion models. This approach can introduce an additional potential for error that may limit the value of the resultant predictions.

(5) Projections of activity proposals and their effects become increasingly more uncertain as the future time boundary is extended. Firm commitments to

development activities far into the future is rare, and to estimate emissions from uncertain future proposals can lead to inaccuracies in future emission levels or ambient air quality concentrations. However, failure to include these more speculative possibilities can lead to the erroneous conclusion that emission levels will decline in the future. Regardless of the approach taken, the assessor should be aware of the probability that far reaching future plans will likely be modified as the timeframe draws closer.

(6) Public participation can be directly incorporated into this analysis process during the application of the factor weights and effects intensity ratings. By default, public involvement is also incorporated in this analysis through its inclusion in the preparation process of any community planning documents utilized, and during the individual project EIA process for each activity that incorporates this analysis.

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Chapter 7

Summary, Recommendations and Conclusions

RESEARCH SUMMARY

The CEA process, as well as the entire EIA process, is meaningless unless the gathered and derived information can be used in decision making. A key component in the information development is the determination of the importance of the predicted effects in context with surrounding activities. To accomplish this, it is vital to provide decision makers with the significance of the environmental effects resulting from the total human influence on the study area. One component of this total influence is the cumulative effect to air quality.

EIA professionals have struggled with cumulative effects for over a decade. Multiple methods and ad hoc approaches have been applied to various proposal evaluations but none have met with widespread acceptance. Generally, this is due to the complexity of the approach and severe limitations in the range of application. The procedures resulting from this research were developed for and applied to U.S. Air Force installations. However, by focusing the analysis to the effects on an environmental medium, air quality, rather than project type or affected ecosystem, the resulting methods are useful for a broader range of applications.

The intent of this research was to alleviate some of the difficulties associated with CEA by developing a practical, step-by-step method for application to real world development actions.

The overall 8-step cumulative air quality effects assessment (CAQEA) method was derived through this research and presented in Chapter 2. From this, procedures were developed and presented in subsequent chapters that outline the required efforts for each step's accomplishment. The first step of the overall method is simply a clarification of the approach to the analysis. Selecting an appropriate cumulative effects definition was found to be necessary due to the range of conception, and in some cases misconception, on how to approach CEA. The second step was designed to ensure that a concerted effort is made to include and document past, present, and reasonably foreseeable future actions (RFFAs), both internal and external to the subject agency, in CEA.

The developed method organizes the RFFA determination process into a methodical, defensible 8-step procedure. Using this process, agencies can show why an action is, or is not, included in a CEA. Since there are no penalty provisions associated with NEPA, if an agency does not voluntarily make the good faith attempt, the only recourse left to concerned groups and individuals is to convince the court that the analysis is inadequate, therefore delaying, or possibly canceling, proposal implementation. This approach to RFFA determination limits the likelihood of legal delays and provides for a more complete analysis than the techniques used in current practice.

Quantification of cumulative effects facilitates the determination of an individual proposal's influence in context with surrounding activities. The air quality model classes determined to be appropriate for CEA are Simple Area Source, Rollback, and Box. These classes do not require extensively detailed input information. In part, this contributed to their selection since information regarding future proposals is usually limited. More refined modeling techniques require input data that is unavailable. Where there is insufficient

ambient data to apply even screening level models, percentage change in emissions can provide a contextual framework for assessing the significance of air quality effects. Ambient data is often limited where there is little concern over reaching or exceeding a stated standard.

Determination of the significance of the cumulative air quality effect in an area can be accomplished through evaluation of the air quality issues important to human, ecological, and developmental sustainability. Application of 18 factors in a weighted matrix format allows for a structured analysis, coupled with professional judgment, that is practical, defensible, and comparable to direct project impacts. The approach to air quality effects significance presented in Chapter 5 also allows for improved insight into cost effective mitigation opportunities. Mitigation need not be restricted to the specific proposal generating the NEPA analysis requirement. Attention can be better focused on the environmental damage inflicted by considering all human influence. Therefore, limited mitigation resources can be applied where they are the most effective, regardless of proponent agency. Presentation of air quality effect issues and mitigation opportunities in this format facilitates understanding and acceptance of decisions made and the associated costs and benefits.

Public participation can be directly incorporated into this analysis process during the application of the significance ratings. By default, public involvement is also included through the development process of any community planning documents utilized, and during the individual project EIA process for each activity where the CEA results are incorporated.

Quantitative uncertainty was found to be an important, and often overlooked, aspect of any predictive method. Documentation of the predictive model uncertainty, or error factor, within the CEA report, will provide the decision maker with a sense of the validity of the predicted results. Documentation of the uncertainty also reduces the likelihood that resultant predictions are viewed as "absolute fact" by decision makers.

Projections of activity proposals and their effects become increasingly more uncertain as one looks farther into the future. Firm commitments to development activities far into the future are rare. Estimating the emissions from these uncertain future proposals can lead to inaccuracies in future emission levels or ambient concentrations. However, failure to include these more speculative possibilities can lead to the erroneous conclusion that emission levels will decline in the future. Regardless of the approach taken, it is important to be aware of the probability that far reaching future plans will likely be modified as the timeframe draws closer. Therefore, it is vital to update the CEA study on a periodic basis. Without this updated information, the value of the predicted data becomes increasingly limited as time progresses.

PROBLEM ISSUES AND RECOMMENDATIONS

Ambient air quality is considered to be one of the best monitored and controlled physical environmental media. However, problems were identified when collecting information relative to this analysis. Even though classified as "in compliance with standards," minimal ambient monitoring data was available relative to the study area in the

southwestern United States. This is a situation not uncommon across the United States. The available emission inventory information from state summary reports was dated or incomplete. Some industrial sources reported emissions based on 10 year old inventories. Others had no inventory date listed at all. These data gaps highlight the need for improved monitoring programs in air quality and probably other environmental areas.

Private industrial sources were reluctant to provide information regarding their air pollutant emissions. Information was unobtainable regarding compliance with permits or even quantities of natural gas consumed. Some company representatives expressed concern that even the state summary data was available to the public. Improved public relations programs with private industry are needed so that individual sources do not feel threatened when questioned about their activities.

Air quality is only one part of the environment that is influenced by human activity. It is important to address, at least in a scoping exercise, the potential for cumulative effects relative to every environmental medium or resource included in the project specific impact assessment. Additionally, methods developed for CEA should consider multimedia effects and transmedia impacts.

Portions of this research can be used, or modified, to address other media. For example, the overall 8-step CAQEA method presented in Chapter 2 could easily be modified to address other physical media. The approach to the development of the RFFA list to be evaluated is applicable to all environmental components, including non-biophysical environment areas such as socio-economics, visual aesthetics, culture, and history. And, the significance determination multi-criteria decision making matrix approach can be applied to

other environmental components. The modification required for other applications is the development of factors applicable to each component addressed and appropriate importance weightings and intensity levels.

CONCLUSIONS

This research study presents the development and application of one possible approach to cumulative air quality effects assessment. The intent of this study was to develop a method and provide a practical example of its application. The holistic approach developed through this research can be used to evaluate all major development activities in context with the daily influences of modern society. Such an evaluation provides insight into the sustainability of the area at current and predicted future activity levels. Assessors should not restrict themselves to following the exact order of the method steps. The step sequences are intended to guide the assessor's thought processes, not dictate the chronology of the step applications. Further, it can be useful to revisit steps as new information becomes available.

EIA is a lengthy, resource intensive process even without the added burden of CEA. Expansion of the existing documentation on environmental resource assets and constraints included in Air Force base and community development plans to include CEA allows for more widespread, uniform, environmentally conscious decision making than separate CEA attempts in individual NEPA documents. Additionally, this approach also maximizes the utility of limited evaluation resources since the results of a single analysis can be

incorporated into multiple environmental assessments (EAs) and environmental impact statements (EISs).

Appendix A

(Supplement to Chapter 4)

Appendix A

Air Quality Model Classifications

OVERVIEW

Air quality models have been classified by the modeling technique, or approach, used to simulate the real world conditions. A classification scheme is presented in Figure A.1 which is a compilation of the various model classifications presented by Seinfeld (1986), Szepesi (1989), Zannetti (1990) and the United States Environmental Protection Agency (USEPA) (1993). The primary division of models is the separation of

- **physical models** - small scale, laboratory representations of actual phenomena, and
- **mathematical models**. - a set of analytical or numerical algorithms that describe the physical and chemical aspects of the actual phenomena (Zannetti, 1990).

PHYSICAL MODELING

The types of models under the physical classification include wind tunnels, liquid flumes, and towing tanks. The calculations used to interpret the data collected are typically a combination, or mix, of Eulerian and Lagrangian techniques. Physical models are primarily of importance in investigating the dispersion of pollutants for configurations too complicated for mathematical modeling techniques (Szepesi, 1989).

Wind tunnels have been employed to evaluate building wake effects. Towing tanks have been used to simulate pollutant flow and dispersion around and through saddles between mountain peaks. And, liquid flumes have been used to investigate the mixing and

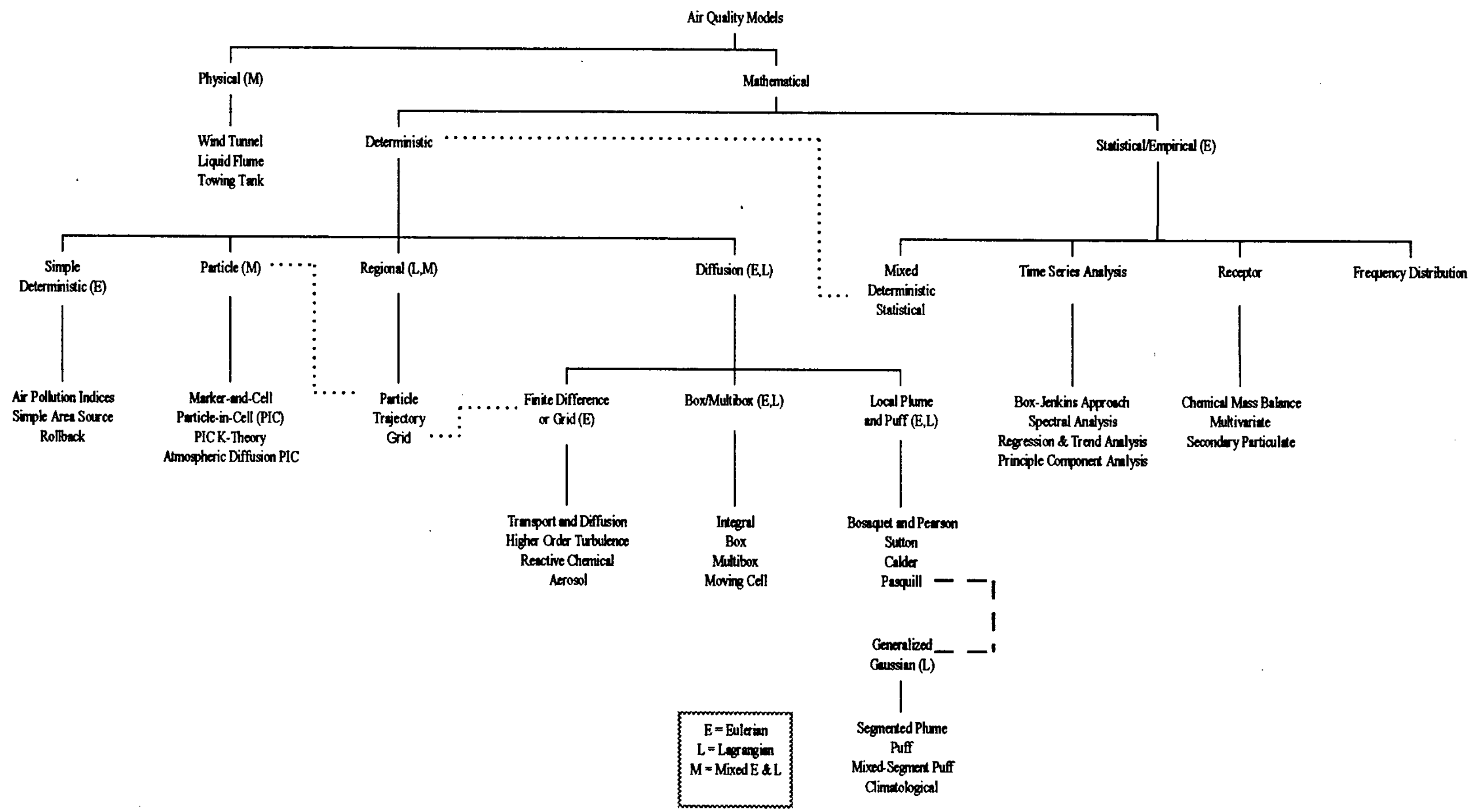

Figure A.1: Air Quality Model Classification

reentrainment of plumes resulting from multiple mechanical draft cooling towers (Szepesi, 1989).

The complex localized effects evaluated with physical models, while important, are not of primary concern when assessing air quality effects over a regional area. The remainder of the available techniques, under the mathematical classification, apply calculations involving the available data to a variety of situations where they have been validated through observation of real world conditions. These techniques, or model types, include those which can be applied to regional, long term analysis.

MATHEMATICAL MODELING

Many of the methods available for approximating atmospheric phenomena, such as diffusion, employ numerical solutions. Methods for numerical analysis include: finite difference methods; finite element methods; and splitting methods. Use of finite difference methods involves defining a grid over the spatial domain of interest and partial derivatives are approximated by divided difference quotients which eventually leads to a set of difference equations that can be used to obtain the approximate solutions. Finite element methods are a refined form of the finite difference in which the spatial domain is zones with approximation solutions for each zone. Because these two methods can become extremely complicated when expanding to two or three dimensions, splitting methods were developed to approximate multidimensional problems with a series of one-dimensional problems (Seinfeld, 1989).

Mathematical modeling of atmospheric pollutant diffusion is commonly based in one of two approach methodologies, Eulerian and Lagrangian, or in some cases, a

combination of both. Zannetti presented an illustration of the basic difference between the two approaches as shown for the frame of reference for the evaluation of a parcel of air in Figure A.2.

In general, the Eulerian approach describes the behavior of the pollutant species relative to a fixed coordinated system, such as in heat or mass transfer phenomena. Eulerian methods estimate pollutant concentration statistics using the statistical properties of the velocities measured at fixed points in the evaluated fluid, e.g., air. The positive aspects of this type of approach include easy measurability of the required statistical properties and the direct applicability of the mathematical expressions to situations where chemical reactions are taking place. The drawbacks to this approach include difficulties in expressing the fluid velocity over time and a lack in mathematical closure (Seinfeld, 1989).

The Lagrangian approach describes the behavior of the pollutant species relative to the moving fluid. This approach estimates pollutant concentration statistics in terms of the statistical properties of the displacements of groups of particles released in the fluid. No mathematical closure problem exists for the Lagrangian techniques; however, applicability is limited by the difficulty in accurately determining the required particle statistics. Also, Lagrangian equations cannot be directly applied to nonlinear chemical reactions (Seinfeld, 1989).

Each approach is valid for diffusion modeling dependent on the specific situation and available information (Seinfeld, 1989). Use of any mathematical approximation theory in air quality modeling requires assumptions and approximations to be made that induce some of the error and uncertainty associated with modeling.

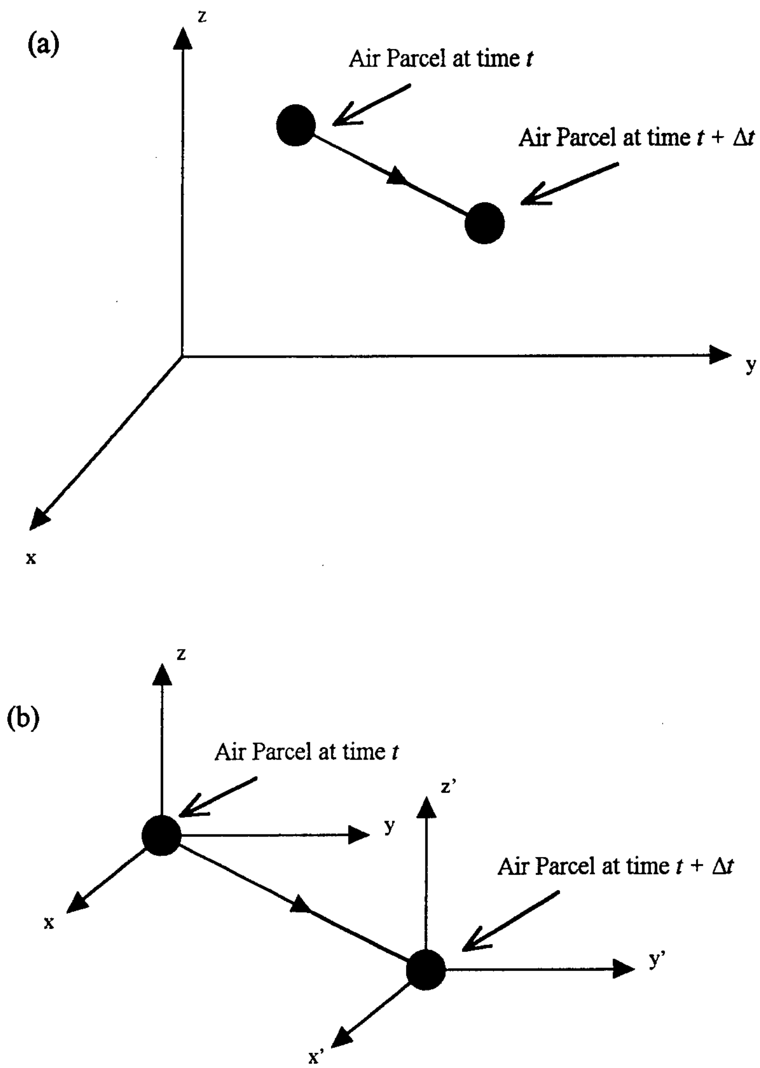

Figure A.2: Comparison of Eulerian (a) and Lagrangian (b) Reference Systems (from Zannetti, 1989)

Mathematical techniques have been divided into two primary categories (Zannetti, 1990):

- **deterministic** - those based on fundamental mathematical descriptions of cause and effect atmospheric process relationships; and,
- **statistical** - also referred to as empirical, which are based upon semiempirical statistical relationships among available data and measurements.

Statistical models typically employ Eulerian calculations and deterministic approaches, being of wider range, include Eulerian, Lagrangian, and mixed Eulerian-Lagrangian calculations (Szepesi, 1989).

Statistical Modeling

Statistical models are useful for real-time, short-term forecasting, where the information available from trends in measured concentrations is more relevant that the projections obtained through deterministic analysis (Zannetti, 1990). Statistical models establish close relationships between estimates of pollutant concentration and actual measured values obtained under similar conditions. They typically have low development costs and resource requirements (Szepesi, 1989). Statistical models can be further delineated into time series analysis, receptor, frequency distribution, and mixed deterministic-statistical models (Zannetti, 1990).

Time Series Analysis

Time series analysis techniques can be used to determine the variability of and correlation between pollution and meteorological data and also to forecast future

concentrations of pollutants based on past and current concentrations combined with meteorological data (Szepesi, 1989). The techniques employed in time series analysis include: the Box-Jenkins approach; spectral analysis; regression analysis; trend analysis; and, principle component analysis. Each of the time series analysis approaches can be used to analyze a time series of concentrations to evaluate intrinsic variations without additional influencing information or with other parameters, such as meteorological or emission inputs, to incorporate deterministic relationships within the statistical framework. They can also be applied in either a "batch" or "real time" mode (Zannetti, 1990).

The Box-Jenkins method is considered to be the most cost effective of the time series analysis approaches and has been applied to the evaluation of meteorological and air quality measurement patterns. Spectral analysis provides the assessor with a means of identifying particular cycles in the data and regression and trend analysis allow the evaluator to fit the known data to a line or curve and use it to forecast or project future activity. Principle component analysis incorporates the same evaluative techniques as the regression analysis, however in this case, the principle meteorological data and pollution components observed are used to predict other pollutant concentrations (Zannetti, 1990).

Statistical models are not applicable beyond the range of conditions included in development and optimization (Szepesi, 1989). As stated earlier, statistical models have been developed for short-term forecasting. Time series analysis models often use techniques for forecasting based on past and current data applied to correlation and regression analyses (Szepesi, 1989).

Receptor Modeling

Receptor models evaluate air pollutant concentrations from the opposite view of other modeling techniques. Rather than evaluate how emissions travel from the source to the receptor, they look at the observed ambient concentration at the receptor and work back to the emission sources, without reconstructing the dispersion pattern, and determine the appropriate proportion of the receptor concentration that is attributable to each source. Receptor models require that information on source emission composition, emission rates, and ambient concentrations be known (Zannetti, 1990).

Chemical mass balance (CMB) receptor models can be used for primary pollution source tracking (Zannetti, 1990). Multivariate receptor models combine CMB with factor analysis. Factor analysis is a tool in statistics that uses empirical orthogonal functions to evaluate quantity variance with minimal factors (Szepesi, 1989). Modifications, or hybrids, have been proposed to the receptor model to allow it to be used to simulate the activities of secondary particulate matter, such as the transport and deposition of sulfates. However, these, as with most receptor models, are still under theoretical and empirical development (Zannetti, 1990).

Because receptor models evaluate the observed concentration at the receptor location and then attempt to determine source contributions, they may be more appropriate for analysis of existing conditions than for forecasting future effects.

Frequency Distribution

The frequency of occurrence of a concentration of an air pollutant that exceeds an established air quality standard or exceeds some other level that is determined to be of

significant interest can be determined, when air quality data is available, with a frequency distribution model. Since the concentration of an air pollutant is inherently a random variable, evaluation of the probability density function (pdf) and its autocorrelation structure can be used to predict the statistical probability of future exceedences (Zannetti, 1990).

The pdf for a random variable, x, is the probability distribution, or formula, that results in the probability of the random variable, $p(x)$, whether discrete or continuous, associated with each possible value of x (Mendenhall and Sincich, 1995). The autocorrelation function is that which quantifies the serial relationship, or behavior, of a time series of random variables, such as air pollutant concentrations. The autocorrelation function provides the assessor with information about the behavior of the random variable near high and low peaks. High, positive autocorrelation for an air pollutant would indicate that air pollution levels would remain high after a peak value is observed and time periods of low pollution levels would typically follow a low concentration observation. Unfortunately, both pdf and autocorrelation tend to vary with season and even with the hour of the day (Zannetti, 1990).

Mixed Deterministic/Statistical Modeling

Depending on the availability of statistical data, semiempirical methods and real-time filters can be used to improve the forecasting capability of a deterministic prediction model. Kalman filters have been used to improve the prediction accuracy of air pollution episodes and pollution control simulations. Care must be taken, however, when applying a Kalman filter to an air pollution problem. Due to the high-dimensionality of the resulting equations, such as matrices of dimension 4000 x 4000, it is necessary to use some algorithm

or regression equation to reduce the complexity. Unfortunately, this also results in a loss of the ability of the model to use the actual, real world data. Therefore, the forecasting performance of the filtered model is reduced (Zannetti, 1990).

Deterministic Modeling

Deterministic models are considered to be the most important subset of mathematical modeling techniques for use in air quality evaluation. "The ability to model atmospheric dispersion and to predict pollutant concentrations from a proposed new source are important parts in air pollution engineering" (Cooper and Alley, 1994). If properly calibrated and used, deterministic air quality models can provide "an unambiguous assessment of the fraction of responsibility of each pollutant source to each receptor area, thus allowing the definition and implementation of appropriate emission control strategies" (Zannetti, 1990). These emission control strategies can range from individual pollutant control devices, to activity siting and regional emissions allocations. Those models categorized as deterministic include: simple deterministic; particle; regional; and, diffusion.

Simple Deterministic Modeling

The simple deterministic models are presented as algebraic relationships based on empirical data. Air pollution indices, simple area source models, and rollback models are included in this category. An air pollution index presents air pollution information, such as

pollutant concentration, as a single number or number set (Szepesi, 1989). The key traits desirable for inclusion in an air quality index are as follows (Canter, 1998):

(1) Easily understood by the public.
(2) Not inconsistent with perceived pollution levels.
(3) Meaningful in a spatial sense.
(4) Includes the ability to address all major pollutants.
(5) Involves only simple calculations with reasonable assumptions.
(6) Rests on a reasonable scientific basis.
(7) Relates to standards and goals for ambient air quality.
(8) Relates to episode criteria including significant harm levels.
(9) Day-to-day variations can be demonstrated.
(10) Conditions can be forecast a day in advance.

While the level of detail of air pollution information provided by an index is low, the information that is provided for dissemination to the public requires no technical background in environmental areas to understand.

Simple area source models are useful for initial screening of atmospheric pollutant concentrations in urban areas. Primarily, this type of evaluation is based on emission source strength patterns within the area and average wind speed and direction. Gifford and Hanna presented a simple area source formula in 1973 given by (Szepesi, 1989):

$$C = \frac{c_1 Q}{U}$$

where

C = annual average air pollution concentration,
Q = source strength per unit area,
U = annual average wind speed, and
c_1 = parameter weakly dependent on city size.

One expression for calculating c_1 is:

$$c_1 = \sqrt{2/\pi}\, X^{1-b}\left[a(1-b)\right]^{-1}$$

where

X = distance from receptor to the upwind edge of the area source

a,b = constants defined by the vertical atmospheric diffusion length $\sigma_z = aX^b$

Rollback models relate air quality forecasting to historical ambient air quality data and emission growth trends. This type of model has historically been used in air quality maintenance planning as an estimation method for determining emissions reductions required to comply with air quality maintenance area standards. The simple form of the model estimates future pollutant concentrations using the formula (Szepesi, 1989):

$$C_F = B + kE_F$$

where

C_F = projected concentration
B = background concentration
E_F = future emissions estimate, and
k = a proportionality factor which incorporates meteorology, source distribution, and other source-receptor variances.

One expression for calculating k, based on present emissions and observed maximum pollutant concentrations is given as:

$$k = \left(\frac{C_P - B}{E_P}\right)$$

where

C_P = maximum pollutant concentration, and
E_P = present emissions.

The assumptions inherent in the application of rollback models include: measured maximum concentrations represent the actual maximum in the study area; maximum predicted ambient concentrations are not inconsistent with meteorological conditions at the time and location of the maximum concentration measurements; pollutants are nonreactive; and growth factors can be applied in a spatially homogeneous manner to a distribution of

pollutants over the study area that does not undergo temporal transformation (Szepesi, 1989). While the method is titled "rollback," the temporal direction in which the model is applied is irrelevant. The model can be used to project future emissions based on present ambient concentrations or to determine historical emission growth rates based on present ambient concentrations and known past ambient concentrations.

Particle Models

The next category of deterministic modeling, particle models, evaluates pollutant particles as they pass through a Eulerian grid. The spatial distribution of the pollutant being analyzed is represented by several Lagrangian particles of constant mass transported through a hypothetical velocity field consisting of a combination of the actual velocity field plus a turbulent flux approximation field. This allows the model to simulate the random motion observed in actual pollutant particle advective movement. There are several particle models available, however, the most common of these are: Marker-and-Cell (MAC); Particle-in-Cell (PIC); Particle-in-Cell K-Theory (PICK); and, Atmospheric Diffusion Particle-in-Cell (ADPIC) (Szepesi, 1989).

The MAC approach, one of the earliest attempts at particle modeling employs massless particles to define spatial orientation within the fluid field. The PIC method modifies this idea to include particle mass in order to evaluate compressible flow problems. In this method, particle position changes are made consistent with the laws of conservation of mass, momentum, and energy. Additionally, PICK and ADPIC include the capability to evaluate the diffusion characteristics of the particles (Szepesi, 1989). Particle models can be applied, as originally intended, to a specific emission source or receptor area.

Additionally, they can be adapted for application on a broader scale when conditions and information availability are favorable.

Diffusion Modeling

Perhaps the most intensively explored category of deterministic air quality modeling is that of atmospheric diffusion modeling. This type of modeling approach primarily involves Eulerian and Lagrangian mathematical analysis and can be separated into three main sub-categories. They are: box and multibox modeling; finite difference or grid modeling; and local plume and puff modeling.

Box and multibox modeling techniques such as the integral, box, multibox, and moving cell are based on calculations using the integral form of the diffusion equation over a volume or region of air associated with: an urban area; a deep valley or basin; or a subvolume of either. This type of analysis assumes that the pollutants and the air are well mixed within the defined volume. However, reactions and removal processes, such as deposition, are permitted within the defined volume (Szepesi, 1989).

The integral method has historically been applied to several areas, including boundary layer aerodynamic problems and evaporation problems. This method has more recently been applied to air quality problems. The results of the calculations define a concentration boundary layer thickness (see Figure A.3) with accuracy that is comparable to more complicated methods (Szepesi, 1989).

The simple form of the box model is mathematically expressed by the equation (Canter, 1996):

$$C = \frac{Qt}{xyz}$$

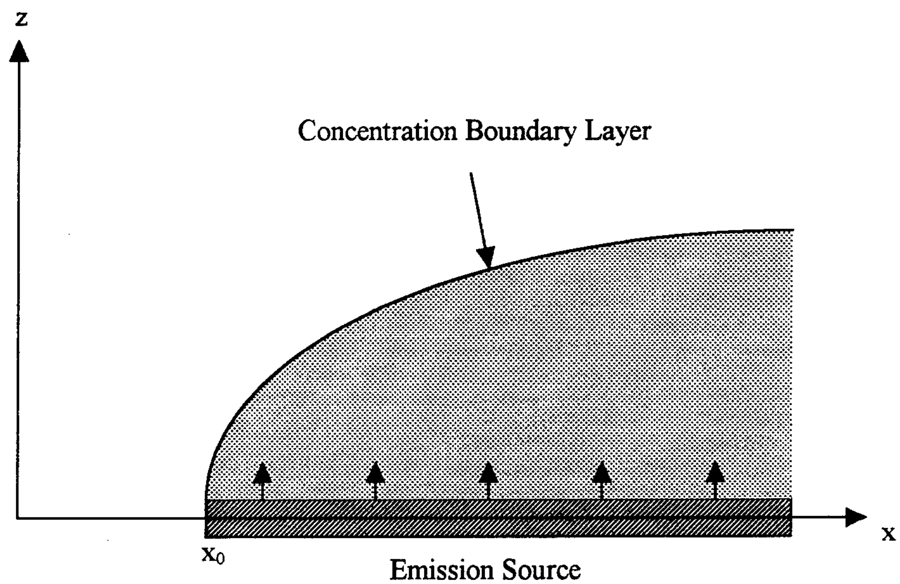

Figure A.3: Concentration Boundary Layer Determined with Integral Method (from Szepesi, 1989)

where

> C = average concentration of pollutant (< 20 μm diameter if modeling particulates), μg/m^3
> Q = flow rate of pollutant (< 20 μm diameter if modeling particulates) from emission source, μg/sec
> t = time period for which uniform mixing assumption is valid, sec
> x = downwind dimension of box, m
> y = crosswind dimension of box, m
> z = vertical dimension of box, m

and is graphically depicted in Figure A.4. The dimensions of the box are determined based on average wind speed and terrain for x, average wind speed source configuration and terrain for y, and limiting inversion height and terrain for z. Box models can be used for single and multiple point, line, and area sources or combinations of these source types (Canter, 1996).

The multibox model expands the concept of the box model by dividing the evaluated volume of air, or airshed, into 2-dimensional or 3-dimensional arrays of boxes. The box properties, such as inversion height, wind speed, and volume, can vary between boxes. The modeled pollutants travel between adjacent boxes through advective forces only. No diffusion across box boundaries is permitted in this method. Multibox models have the advantage over single box models in that time variation of inversion heights can be incorporated, and the multiple box dimensions can be selected to conform to local topography. The negative aspects of the multibox model include: failure to address vertical diffusion; and excessive mathematical calculation requirements. Modifications have been incorporated into the multibox model for specific applications to include vertical pollutant concentration distribution (Szepesi, 1989).

Evaluation of a hypothetical column of air traveling along an air trajectory over a study area has been developed into the technique known as moving cell modeling. As the

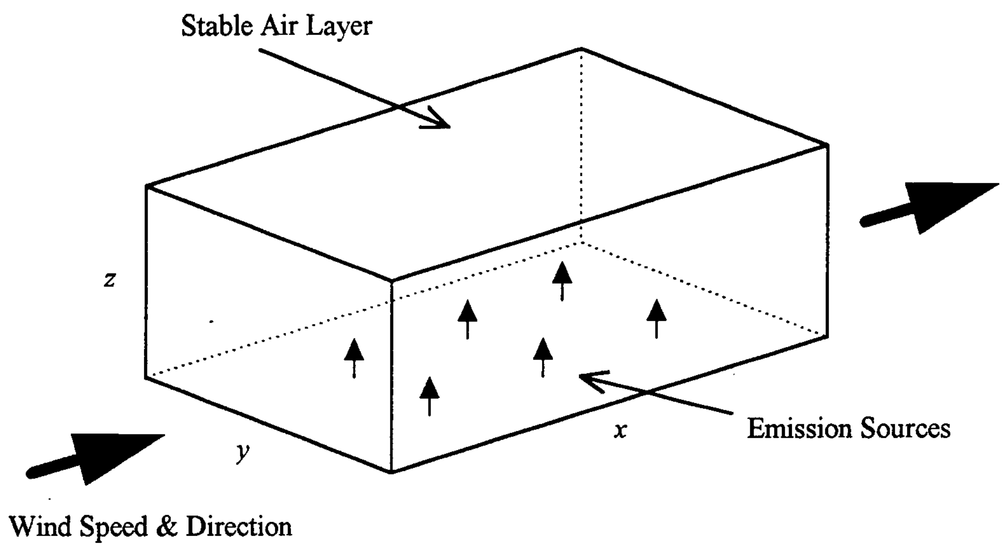

Figure A.4: Simple Box Model (adapted from Canter, 1996)

column moves across the study area, pollutants from encountered emission sources enter it through its base. Once inside the cell, chemical reactions may take place. However, the model does not account for diffusion processes in the column. It does not allow for wind field convergence and divergence or vertical advection. Even with the deficiencies resulting from the primary assumptions in the model development, a study conducted in Edmonton, Alberta modeling ground level concentrations of NO_x and CO resulted in predictions with average error factors of only 1/2 to 2 (Szepesi, 1989).

Finite difference or grid modeling, physically more realistic than most methods, produces approximations of urban and regional pollutant concentration over an entire grid, rather than just along a given trajectory. They are generally applied to the calculation, by finite difference approximation of transport and diffusion equations, of short-term concentrations of reactive pollutants and pollution episode analysis. They are used to evaluate pollution episodes in urban areas, deep valleys, and mountainous regions, therefore, the meteorological component of grid modeling is significant. Calculation of wind fields over urban areas and complex terrain has been found to be complicated and computer intensive. Wind channeling through valleys, boundary layer instabilities, plume impingement on ridges, and vertical mixing due to terrain contours are some of the phenomena which need to be addressed for accurate results. Grid modeling techniques are being developed relative to transport and diffusion, higher order turbulence, reactive chemical, and aerosol modeling. While these models are extremely versatile, the complexity in the incorporation of chemical reaction effects, atmospheric thermal structures, and deposition mechanisms make them time and resource intensive (Szepesi, 1989).

Given the proper diffusion coefficient and wind data inputs, local plume and puff models are considered to be the most reliable air quality models. Local plume and puff models have been used in air pollution control strategy evaluation, land use planning, facilities siting, and highway and aircraft use impact assessments. The basic form of the plume equation is (Szepesi, 1989):

$$C(x,y,0;H) = A \exp\left[-\left(\frac{y}{\sqrt{2}\,\sigma_y}\right)^r - \left(\frac{H}{\sqrt{2}\,\sigma_z}\right)^s\right]$$

where

C(x,y,0;H) = ground level concentration of pollutant emitted from an elevated point source with effective height *H*

The remaining parameters are dependent on the particular model chosen, e.g., Bosanquet and Pearson, Sutton, Calder, or Pasquill approach. As an example, the Pasquill plume model uses the following for the remaining parameters (Szepesi, 1989):

$$A = \frac{Q}{\sqrt{2\pi}\,pqx^2U}$$

and

$$\sigma_y = qx \qquad \sigma_z = \sqrt{2}\,px$$

where

Q = source strength
p = numerical coefficient in the eddy diffusivity $K_z = pUz$
q = empirical coefficient
x = downwind distance
U = mean horizontal wind velocity
σ_y, σ_z = horizontal and vertical spread parameters.

The Gaussian plume model of Pasquill is the most commonly applied of all the available theoretical formulae (Szepesi, 1989). The generalized Gaussian model approximates a binormal distribution of the dispersion characteristics of atmospheric

pollutants. In other words, the concentration dispersion exhibits a normal distribution vertically, and also horizontally along the downwind, x, axis. The Gaussian equation for modeling the binormal distribution of pollutant concentration from an elevated source with no atmospheric reactions is (Cooper and Alley, 1994):

$$C = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left\{\exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right\}$$

where

C = steady state pollutant concentration at a point (x,y,z), $\mu g/m^3$
Q = emissions rate, $\mu g/s$
σ_y, σ_z = horizontal and vertical spread parameters, m
u = average wind speed at stack height, m/s
y = horizontal distance from plume centerline, m
z = vertical distance from ground level, m
H = effective stack height ($H = h + \Delta h$, where h = physical height and Δh = plume rise), m. .

A graphical representation of the Gaussian binormal distribution model is shown in Figure A.5. The Gaussian equation can be applied, not only to point sources, but also to line, area, and volume sources.

Many applications of the Gaussian equation use analytical or numerical techniques to perform the necessary spatial integration of the basic form of the equation for evaluation of non-point sources. An alternative to the complexities of this type of mathematical analysis, particularly those involved with the spread parameter functions, is the virtual point method. In this method, the non-point source is approximated with an appropriate upwind virtual point source as illustrated in Figure A.6. This method provides a simple, yet fairly accurate, evaluation of line, area, and volume sources without the complexities of multi-dimensional integration (Zannetti, 1990).

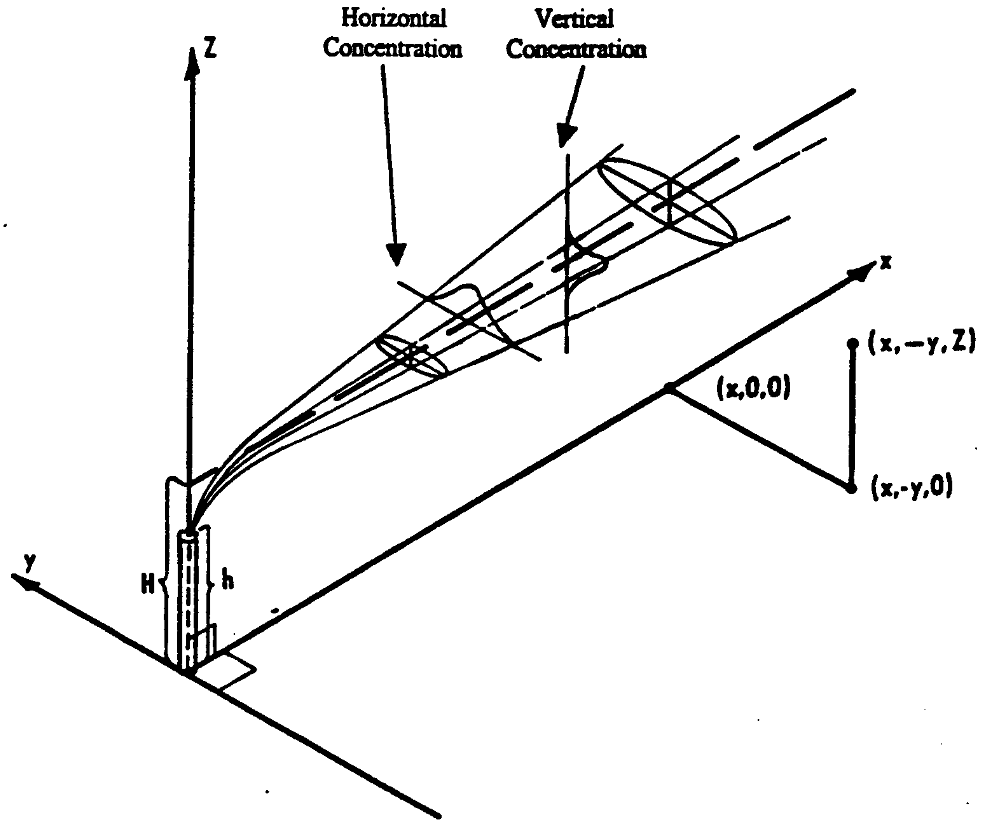

Figure A.5: Gaussian Plume Dispersion (from Turner, 1994).

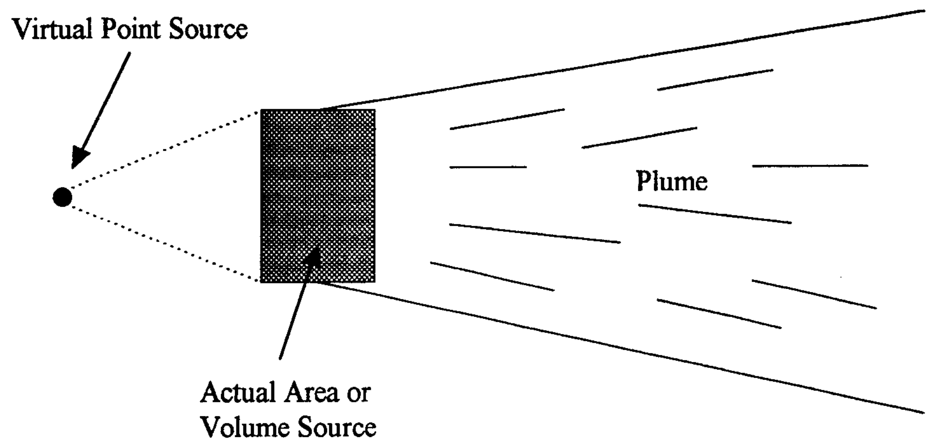

Figure A.6: Virtual Source Simulation of Non-Point Sources (from Zannetti, 1990)

The Gaussian approach has been applied to simulate time-varying pollutant concentration fields with assumptions of a series of steady-state emissions and meteorological conditions to present a separate stationary pollutant concentration field for each time period. This is referred to as climatological modeling. Progressive change in wind speed and direction and multiple receptor locations can be evaluated using the segmented plume model (see Figure A.7). In this model, the concentrations are determined using the original Gaussian formula for a virtual plume for each segment. Each segment generates a concentration field that represents the contribution of the entire virtual plume passing through that segment. The concentration observed by a receptor is that of the closest segment. Other applications of the Gaussian equations include the puff model and the mixed-segment puff model. These models address non-stationary emissions in variable dispersion conditions, similar to the segment models, however, puff methods can also simulate low wind or calm conditions (Zannetti, 1990).

Regional Modeling

Regional models have been developed to simulate and analyze atmospheric pollutant transport over great distances and areas. Particle, grid, and trajectory models have been modified for application to regional analysis. Particle modeling at a regional scale can, unfortunately, be expensive to conduct (Szepesi, 1989). High cost and the requirement for precise emission data limits the value of this type of modeling of future effects on a region. Grid modeling techniques are still in the development stage and therefore are not commonly available for use (Szepesi, 1989).

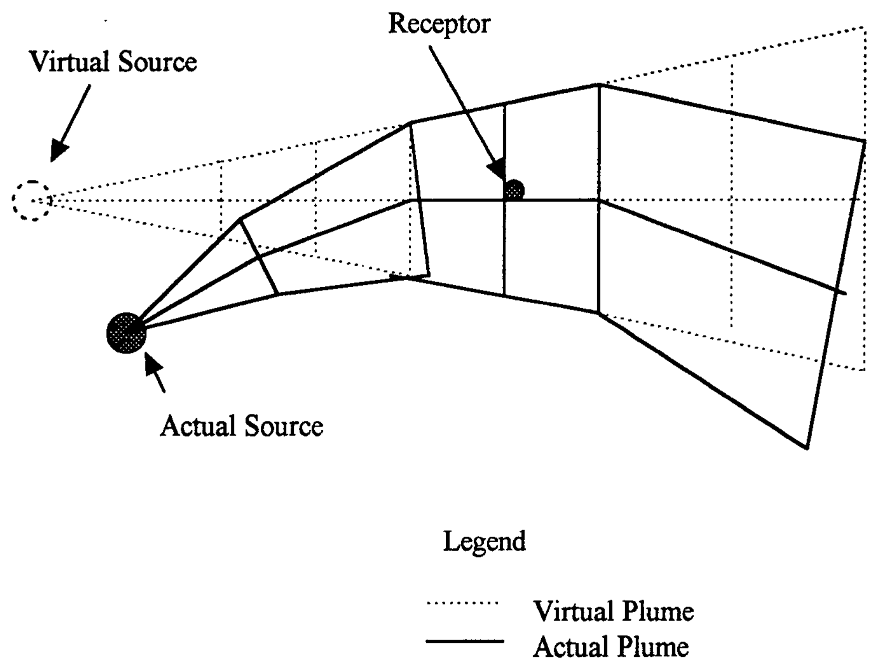

Figure A.7: The Segmented Plume Method (from Zannetti, 1990)

Trajectory models have been developed more extensively and provide for simplified Lagrangian calculation of transport and diffusion of either a limited number of distinct emission sources or an agglomeration of sources within a region. Trajectory models simulate the time dependent behavior of a moving particle in velocity field with temporal and spatial fluctuations. Because of the capability to incorporate heterogeneous velocity (wind) fields, trajectory modeling has proven useful in emission source assessment, complex terrain simulations, urban photochemical modeling, and in large regional scale studies. Unfortunately, trajectory models can not easily model: vertical wind shear effects across a plume; some surface depletion or deposition effects; or complex chemical reactions. Trajectory models are also not well suited to applications using a large number of emission sources within close proximity of each other because of the large number of computations required and difficulties involving plume overlap interaction effects (Szepesi, 1989).

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Appendix B

(Supplement to Chapter 4)

Appendix B

Multimedia Transport and Fate Modeling

OVERVIEW

Environmental pollution does not restrict itself to the initial media to which it is released. Contaminants released to the air can precipitate and deposit on soil or surface waters. Other contaminants released to ground or surface water can find their way into plants or animals and to soil where wind, erosion, and human activities can re-entrain them into the atmosphere. A graphical representation of the media interaction pathways available to atmospheric pollutants adapted from Seinfeld (1986) is shown in Figure B.1. As a consequence, a holistic modeling approach for CEA needs to consider intermedia transport of pollutants. A CEA methodology for air quality does not necessarily need to include multimedia transport calculations within itself, however, consideration should be given to using the outputs of air quality modeling as inputs for CEA models for other media.

MODEL CATEGORIES

Available multimedia fate and transport models can be classified into three primary categories: (1) multimedia-compartmental (MCM) models; (2) spatial-multimedia (SM) models; and (3) spatial-multimedia-compartmental (SMCM) models (see Figure B.2). The MCM models assume all environmental media are well mixed. While air and water pollutant concentrations can be approximated accurately for area or dispersed atmospheric emissions based on this assumption, accurate soil concentration estimates are difficult since the "well mixed" perspective is invalid (Cohen, 1989).

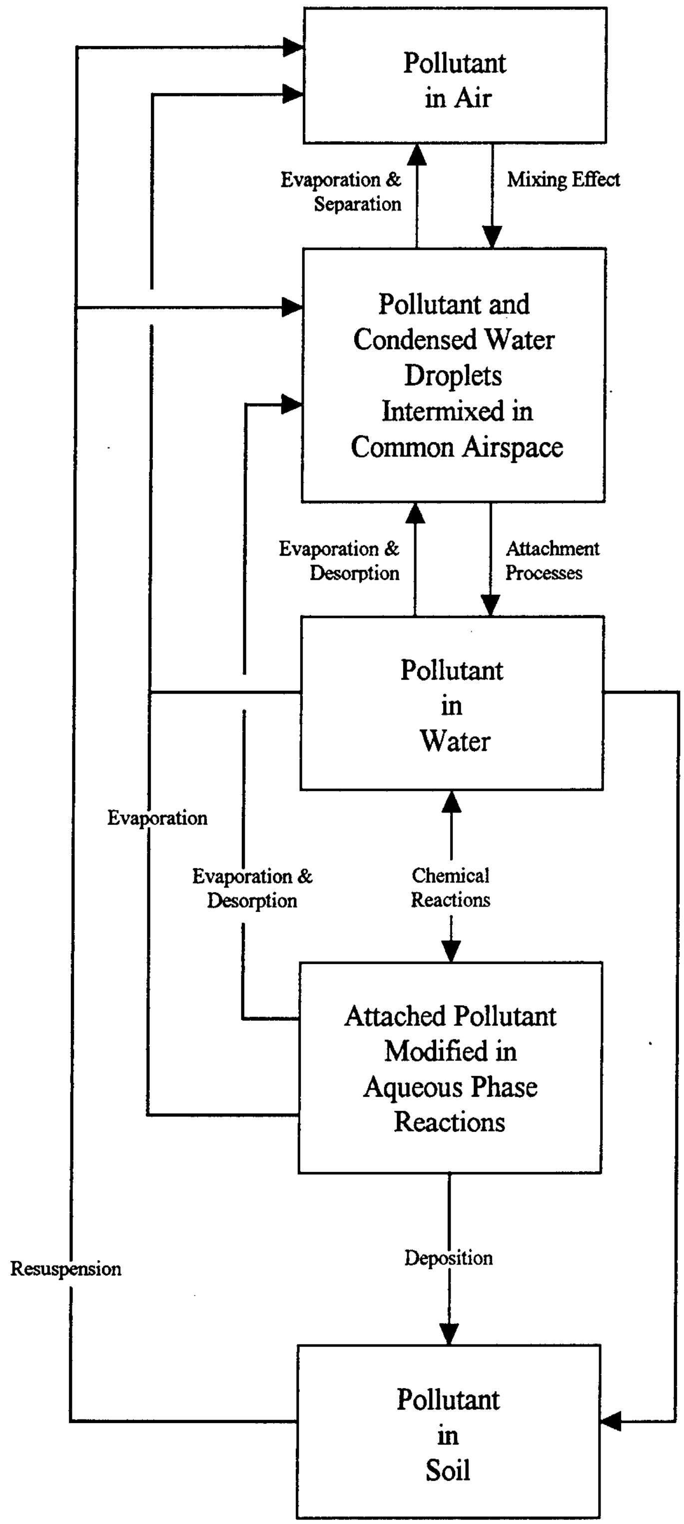

Figure B.1: Pollutant Intermedia Transport Pathways (adapted from Seinfeld, 1986).

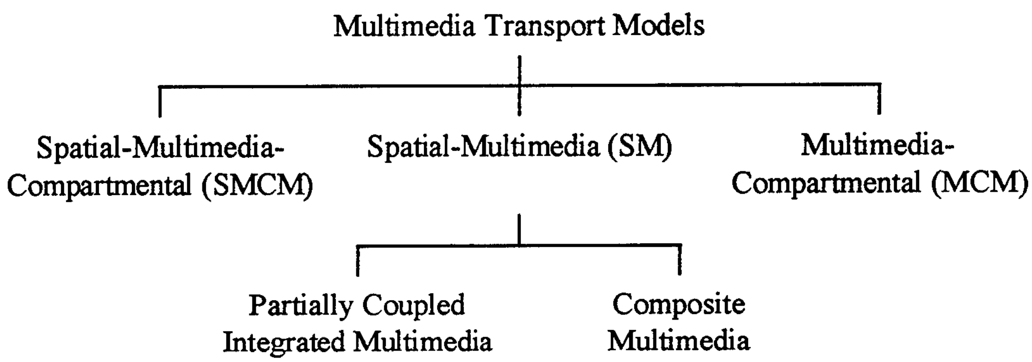

Figure B.2: Multimeda Transport Model Classification

SM models are divided into two sub-classes: (1) partially coupled, integrated multimedia models; and, (2) composite multimedia models. The partially coupled models are single-medium models solved sequentially with the output of each (e.g. air, water, etc.) being shared and managed using a central executive tool or program. The applicability of this type of integrated model is limited by the constraints of the individual modules. Composite multimedia models consist of individual pathway models similar to those in the partially coupled model, however, the pathway modules are not connected (Cohen, 1989). The individual models can be used together by using the output file from one pathway as part of the input to another. The limitation in this approach is that it does not allow feedback to the initial module used. However, this feedback can be manually input by the environmental effects assessor. Finally, the spatial-multimedia-compartmental (SMCM) model is an improvement over the MCM model in that it accounts for treatment of soil and sediment as non-uniform compartments (Cohen, 1989).

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Appendix C

(Supplement to Chapter 5)

Appendix C

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Appendix D

(Supplement to Chapter 6)

Appendix D

Air Quality Cumulative Effects Assessment Application to a United States Air Force Base

INTRODUCTION

Multiple methods and techniques have been developed over the years to assist environmental planners in assessing the effects of human activities on their surroundings. A particular issue of concern is the evaluation of cumulative effects. Cumulative effects assessment (CEA) has been criticized in much of the pertinent literature as being too comprehensive and complex to be incorporated into the project specific impact assessment process (Dixon and Montz, 1995).

Several approach theories and methods for conducting cumulative assessments have been presented along with ideal attributes that should be included. Seminars, conferences, and even court cases, have contributed to what is considered to be necessary for adequate CEA. Often, however, the individuals tasked within an agency with the labor of conducting assessments are left with multiple theories, methods, ideal components, and suggestions that, while valuable, do not demonstrate the rudimentary mechanics of how to get the job done.

This study presents a practical application of a method to identify and offer resolution for the difficulties associated with data collection and analysis for CEA. The appendix is presented as a sequenced application of the 8-step method for cumulative air quality effects assessment (CAQEA) (see Table D.1). These steps incorporate the data collection and evaluation tasks necessary to generate quantitative air quality cumulative effects (CEs) information. By applying the steps to a U.S. Air Force base, a federal facility subject to the National Environmental Policy Act (NEPA), and the surrounding area,

Table D.1: Steps for Cumulative Air Quality Effects Assessment (CAQEA)

1. Select definition of CE to be applied in the analysis.
2. Determine spatial and temporal boundaries.
3. Determine past, present, and reasonably foreseeable future actions to be included in the analysis.
4. Determine baseline ambient air pollutant concentrations and obtain applicable standards or regulations.
5. Develop quantitative and qualitative emission data estimates for the actions determined in Step 3.
6. Determine quantitative and qualitative changes to baseline air quality (determined in Step 4) resulting from evaluated actions.
7. Evaluate the CE significance in context with the air quality impacts of the action originally generating the NEPA requirement and incorporate that significance into the assessment.
8. Include mitigation opportunities for CEs when discussing specific action impact mitigation.

quantitative and qualitative data can be developed in a format applicable to significance determination of cumulative air quality effects in context with the direct air quality effects of an individual major action. The intent is for cumulative effects to be compiled as an independent document and incorporated by reference into individual project impact analyses.

The base selected is intended to represent the average, or norm, of Air Force facilities within the United States. The base consists of a single mission wing with typical support structure. It has an active flight line and is not currently scheduled for base closure. The future activities scheduled for this base are typical of Air Force facilities where the intent is to maintain and improve the current mission capabilities but not take on new mission responsibilities. There are no currently existing mission critical deficiencies. The nearby city is small (approximately 100,000 residents) but is experiencing gradual linear growth (as projected in the city growth trends report) and has a well established industrial and commercial economy. Conducting a study of an Air Force base located in a small population center with relatively few concerns about ambient air pollution allows for the exploration of various data limitation scenarios and the development of evaluation options to apply to each.

STEP 1 -- DEFINITION SELECTION

Step 1 of the method is the selection of a definition for cumulative effect (impact) to be used throughout the study. The intent is to standardize the definition employed by a federal agency to minimize the potential for variation between assessors as to the meaning of cumulative effects (CEs). The definition recommended, and selected for application to this

case study, is the Council on Environmental Quality (CEQ) definition. This definition states that cumulative impacts (or effects) result from

> "the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR 1508.7 as found in Council on Environmental Quality, 1996).

The same definition should be applied when conducting cumulative assessments with respect to other environmental resources as well as in each individual project environmental impact assessment (EIA).

STEP 2 -- BOUNDARY DETERMINATIONS

Step 2 relates to the determination of spatial and temporal boundaries for the analysis. Based on discussions and recommendations in various literature sources, the time frame considered reasonable for air quality cumulative affects assessment (CEA) for application to an Air Force Base (AFB) was 10 years; two years of the "past" and eight years of the "future." This determination was based on the availability of past and current air quality data and the relative degree of certainty that could be applied to plans for future activity.

Regarding spatial boundaries, consideration was given to both the physical airshed and existing political boundaries. Political boundaries can influence the number and types of future actions, significance determinations, and mitigation decisions. Initially, the political boundaries considered were: (1) the AFB property boundaries; (2) the city limits; and (3) the county in which the AFB and city are located. The airshed boundaries were

determined to be linked to the prevailing wind speed and direction. When applying the quantification measures suggested in Chapter 4, spatial dimensions can be determined by considering the distance a theoretical parcel of air would travel given the prevailing wind speed and direction over a time period considered to be reasonable for uniform mixing assumptions. For this example, multiplying the annual average wind speed of 5.66 m/sec and a typical mixing time of 1 hour resulted in a downwind distance roughly equivalent (approximately 12% larger) to the physical length of the developed land area of the city. Also, while valuable information was obtained from county level sources, insufficient data was available to forecast future development for the entire county. Therefore, the analysis was limited to the effects of the AFB in context with the surrounding city. The total geographical area was approximately 268 sq. km (see Figure D.1).

STEP 3 -- ACTIVITIES TO EVALUATE

Step 3 is the determination of past, present, and reasonably foreseeable future actions (RFFAs) to include in the analysis. The 8-Step Conservative Determination Method for RFFAs (see Figure D.2) was applied to the determination of RFFAs. Step 1 of the RFFA method, the determination of boundaries, overlaps with Step 2 of the overall method. The initial boundary determinations were made prior to addressing activities, however, the adjustments made due to data gaps result from information gained in this portion of the analysis.

Past and present activities were considered to be incorporated into the existing air quality determination. Activities addressed included: major, permitted, source activity; natural gas combustion from non-permitted, including household, furnaces and boilers; road

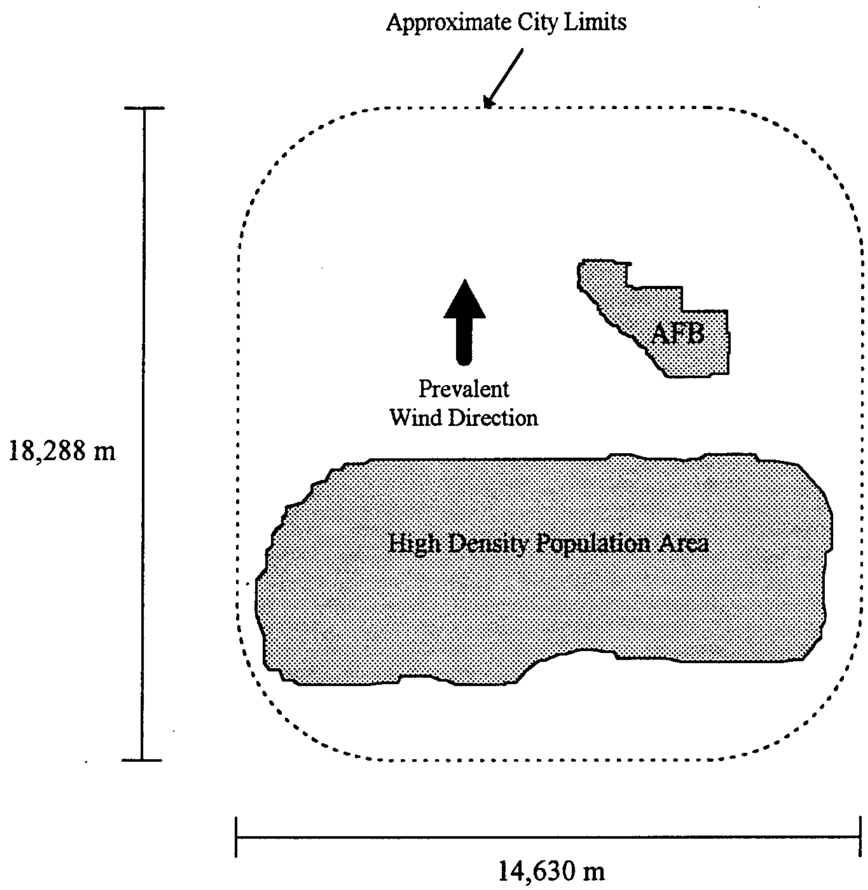


Figure D.1: Approximate Geographical Area for Analysis

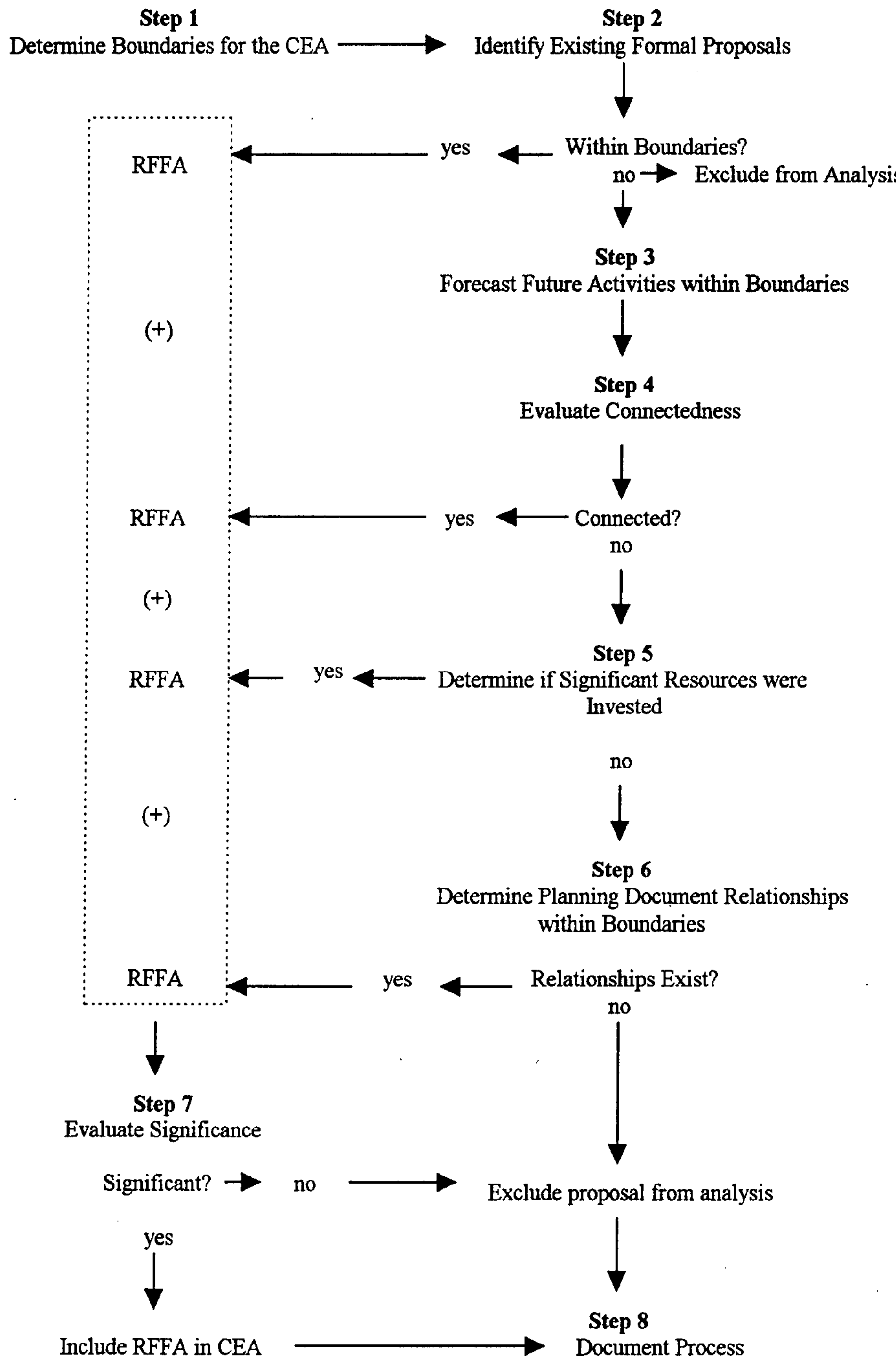


Figure D.2: 8-Step RFFA Determination Method

vehicle use; non-road vehicle use (e.g., aircraft, lawnmowers, etc.); and fugitive emission from solvents, adhesives, paint, waxes, etc.

The RFFA determination steps outline an evaluation process for rational inclusion and exclusion decisions regarding future activities. It is not meant to restrict the assessor from gathering data relative to a specific step prior to the completion of all previous steps. In this case, the requirement for formal proposals within the subject agency was satisfied by the capital improvements program section of the base comprehensive development plan. This plan provided information on over 200 formal and informal development activities from 1996 to 2004. Informal projects were identified with the phrase "project not scoped." The proposals included in this plan were limited to those with an estimated construction cost of $75,000 or greater. Smaller projects activities are typically not projected beyond one year. However, several of the projects that are included would qualify for categorical exclusion under the environmental impact assessment (EIA) process. Therefore, since this planning document does include more activities than just those that would be considered "major federal actions," it is reasonable to exclude any projects that are too small to be incorporated. Due to the apparent comprehensive effort conducted to include future actions in the capital improvements program, no further forecasting was conducted for base proposals.

The city planning office was contacted to determine what, if any, future actions were planned. It was found that the city did not have a comprehensive development plan, however, other planning documents were available. The city had a current version of a transportation development plan which included over 100 transportation related development projects over a 20 year period from 1995 to 2015. Additionally, the city planning office was

able to provide a growth trends study showing the historical population and housing trends from 1985 to 1995. These trends were used to forecast future population estimates and housing requirements. Table D.2 presents the method used to project future populations and housing requirements. The housing requirement projections resulted in annual informal housing subdivision construction projects necessary to meet the anticipated need. Interviews with the city planning staff revealed that no government or private development projects were anticipated over the duration of the study time frame other than housing development.

The resultant list of approximately 300 future projects was evaluated through application of the RFFA determination method. The evaluation of base informal proposals and city formal and informal proposals for steps 4 through 6 was relatively simple. All base informal proposals were identified within existing development program categories (e.g. pavement improvement plan projects), therefore, connections were easily identified. City formal proposals were identified in goal-oriented planning documents applicable within the defined boundaries, and informal proposals were developed from the planning document trend projections. From this list, 145 RFFAs were identified through Step 7 where air emissions were expected and could be estimated and quantified. The original list should be retained for consideration of other media (water, soil, socio-economics, etc.) effects for a complete CEA. Tables D.3 through D.13 present, by category, the RFFAs determined for inclusion in the air quality CEA.

STEP 4 -- BASELINE AMBIENT AIR QUALITY DETERMINATIONS

Step 4 of the CAQEA method (Table D.1) involves the determination of baseline ambient air quality and the identification of applicable standards. From the U.S.

Table D.2: Sample Calculations for Population and Dwelling Unit Projections

1. Project Future Populations

From city growth trends report:

Year	Population
1980	94,201
1990	96,259
1996	102,790

Report shows that the city has experienced steady population increases from 1990 to 1996 with no period of decline.

Average annual increase (1990-1996) = (102,790 - 96,259)/6 ≅ 1088 people/yr

Assuming trend continues...

Year		Population
1997	102,790 + 1088 =	103,878
1998	103,878 + 1088 =	104,966
1999	104,966 + 1088 =	106,054
:	: :	:
:	: :	:

2. Project Future Dwelling Unit Volumes

From city growth trends report:

- Net change in city dwelling units for 1985 to 1995 = +1,408
- 1996 total city dwelling units = 41,259

Average annual dwelling unit increase = 1408/10 ≅ 141 units/yr

Assuming trend continues...

Year		Dwelling Units
1997	41,259 + 141 =	41,400
1998	41,400 + 141 =	41,541
1999	41,541 + 141 =	41,682
:	: :	:
:	: :	:

Table D.3: AFB Water System Project Formal and Informal Proposals

FY95	
1	Install 8-inch Water Main
FY97	
2	Replace 6-inch Water Mains
FY98	
3	Replace 8-inch Water Main
4	Replace 10 and 6-inch Water Mains
5	Replace Equipment at Base Water Plant
6*	Replace Base Water Mains
FY99	
7*	Replace Base Water Mains
FY00	
8*	Replace Base Water Mains

*Informal Proposal

Table D.4: AFB Sanitary Sewer System Project Formal and Informal Proposals

FY96	
1	Repair Sanitary Sewer System Base Wide
2	Repair Sanitary Sewer System Base Wide
3	Repair Avenue Sanitary Sewer
FY97	
4*	Replace Sanitary Sewer Lines
FY99	
5*	Replace Sanitary Sewer Lines
FY00	
6*	Replace Sanitary Sewer Lines

*Informal Proposal

Table D.5: AFB Storm Drainage System Project Formal Proposals

FY96	
1	Correct Drainage in Family Housing
FY98	
2	Repair Storm Drainage Ditch

Table D.6: AFB Natural Gas System Project Formal and Informal Proposals

FY96	
1	Replace Gas Mains
FY98	
2	Replace Gas Mains
3	Replace Gas Mains
4	Replace Gas Mains
FY99	
5*	Replace Base Gas Mains
FY00	
6*	Replace Base Gas Mains

*Informal Proposal

Table D.7: AFB Electrical Distribution System Project Formal Proposals

FY95	
1	Replace Main Electrical Substation
2	Replace Primary Underground Feeder
3	Relocate Feeder Underground
FY96	
4	Relocate Feeder Underground
5	Relocate Feeder Underground
FY98	
6	Replace Deteriorated Servicelines Base Wide
7	Relocate Feeder Underground
8	Relocate Feeder Underground
FY99	
9	Relocate Feeder Underground
FY00	
10	Relocate Feeder Underground

Table D.8: AFB Pavements Project Formal and Informal Proposals

FY95	
1	Repair School Apron, Phase 3
2	Runway Maintenance
3	Construct Hush House Foundation
4	Paint Airfield Markings
5	Runway Overrun Maintenance
6	Repair Road Surface
7	Repair Road
8	Repair Road
9	Construct Parking Area
FY96	
10	Repair School Apron, Phase 4
11	Replace Pavement
12	Runway Maintenance
13	Construct Parking Lot
14	Repair Parking Lots
15	Construct Nature Trail
16	Replace Runway Surface
17	Construct Hammerhead Holding Apron
FY97	
18	Repair School Apron, Phase 5
19	Repair Parking Lots
20	Repair Parking Lot
21	Repair Parking Lot
22	Repair Avenue
23	Pave Underground Manhole Training Area
24	Repair Roads
25	Correct Airfield Drainage
26	Regrade Taxiway Transition Slope
FY98	
27	Runway Drainage Corrections
28	Repair Roads
29	Repair Parking Lots
30	Repair Parking Area
31	Repair Parking Area
32*	Maintenance and Repair of Base Streets
FY99	
33*	Maintenance and Repair of Base Streets
FY00	
34*	Maintenance and Repair of Base Streets

*Informal Proposal

Table D.9: AFB Roof Improvement Project Formal Proposals

FY95	
1	Repair Built-Up Roof
2	Repair Built-Up Roof
3	Repair Built-Up Roof
FY96	
4	Repair Built-Up Roof
FY98	
5	Repair Built-Up Roof
6	Repair Built-Up Roof
7	Repair Built-Up Roof

Table D.10: AFB Facility Construction Project Formal Proposals

CY96*	
1	Construct Civil Engineer Zone 1 Building
CY97	
2	Fire Station Addition/Canopy
3	Housing Maintenance Office
4	Precision Measurement Equipment Laboratory Addition
5	Add/Alter Shoppette
6	Addition to Central Preparation Kitchen and Bakery
7	Construct Consolidated Logistics Warehouse
8	Addition to Chapel Center
9	Construct Training Dormitory
CY98	
10	Alteration and Repair to Physiological Training Building
11	Modify Small Arms Range
12	Construct Medical Readiness Warehouse
13	Construct Medical Readiness Training Facility
14	Construct Media Blast Facility
15	Construct Warehouse
16	Add/Alter Biomedical Equipment Maintenance School
CY99	
17	Addition to Data Automation
18	Office Addition to Chapel 2
CY00	
19	Construct Dental Instrument Processing Center
20	Bio-Environmental Services Building
21	Construct Law Center Addition
22	Construct Logistics Support Facility, Phase 2
CY01	
23	Construct 200 Family Housing Units
24	Replace 50 Family Housing Units
25	Construct Civil Engineer Readiness/Disaster Prep Building
CY02	
26	Construct Aircraft Systems Training Complex
CY03	
27	Construct Aircraft Systems Training Facility
CY04	
28	Collocated Club Addition

*Calender Year (CY) for construction estimated with assistance from base project programmer

Table D.11: AFB Demolition Project Formal Proposals

FY97	
1	Demolish 2 Buildings
FY98	
2	Demolish 8 Buildings
FY99	
3	Demolish 6 Buildings
FY00	
4	Demolish 5 Buildings
FY01	
5	Demolish 1 Building
FY02	
6	Demolish 6 Buildings

Table D.12: Selected Projects from City Metropolitan Transportation Plan[1]

FY95	
1	Upgrade Interstate Bridge Rail, Seal Coat, and Repave
2	Avenue Bridge Rehabilitation
3	Reconstruct Existing 4-lane Boulevard
FY96	
4	Construct Left Turn Lane, Reconstruct/Align Intersection
5	Reconstruct Road
FY97	
6	Reconstruct Existing 4-lane Boulevard
7	Reconstruct Existing 6-lane Boulevard
8	Align Intersection
FY98	
9	Add Turn Bays
10	Add Left Turn Bays
11	Channelize Intersection
12	Redesign Intersections
FY99	
13	Construct 4 Lanes with Turn Bays
14	Widen Road to 36 Feet
FY00	
15	Resurface Street
16	Add Left Turn Bays
17	Reconstruct Intersection
18	Widen Road and Install Left Turn Bays
FY01	
19	Add Shoulders
20	Reconstruct Existing 2 Lanes
FY02	
21	Reconstruct Road, Add Curb and Gutter
22	Widen Road to 36 Feet
FY03	
23	Widen Road to 4 Lanes
24	Redesign Intersection
25	Reconstruct Street and Widen to 4 Lanes
FY04	
26	Cover Open Drainage Ditch

[1]The city plan identifies project needs in 10- and 20-year formats plus additional project needs that were not included for a specific year. The total cost estimate for the proposals far exceeds the expected budget allocations and multiple interest group project priority listings are provided. This table represents a representative sample that can reasonably be expected to be completed within temporal and budgetary constraints. It is intended to represent the expected emission levels, not the actual projects that will be selected.

Table D.13: City Housing Subdivision Development Project Informal Proposals[1]

CY97	
1	Construct 141 Dwelling Unit Subdivision
CY98	
2	Construct 141 Dwelling Unit Subdivision
CY99	
3	Construct 141 Dwelling Unit Subdivision
CY00	
4	Construct 141 Dwelling Unit Subdivision
CY01	
5	Construct 141 Dwelling Unit Subdivision
CY02	
6	Construct 141 Dwelling Unit Subdivision
CY03	
7	Construct 141 Dwelling Unit Subdivision
CY04	
8	Construct 141 Dwelling Unit Subdivision
CY05	
9	Construct 141 Dwelling Unit Subdivision
CY06	
10	Construct 141 Dwelling Unit Subdivision
CY07	
11	Construct 141 Dwelling Unit Subdivision
CY08	
12	Construct 141 Dwelling Unit Subdivision

[1]Based on information in city Growth Trends report.

Environmental Protection Agency (USEPA) Aerometric Information Retrieval System (AIRS), it was determined that the study area was represented by one PM_{10} monitoring station with an annual average concentration of 19 $\mu g/m^3$. The area is considered to be in attainment for all criteria pollutants. Observed data was not available for the other pollutants. Air quality information can also be obtained from the USEPA regional office with jurisdiction over the study area. Lack of ambient monitoring data is a situation common to several areas across the United States; however, information can be obtained, or developed, to represent (or be indicative of) current conditions. One approach is to conduct a complete emissions inventory for the area determined by the spatial boundaries. Once the emission inventory for the area is complete, either the inventory itself can be used as the baseline for comparing future events to current conditions, or modeling tools can be employed to estimate the ambient concentrations. Methods for the development of the emission inventory for the current conditions, as well as future activities, are presented in the discussion of Step 5.

STEP 5 -- EMISSION ESTIMATES

Step 5 of the method is the development of quantitative and qualitative emissions estimates for the activities included in the analysis. To present a true cumulative picture, the operational effect of these actions must be included as well as the construction phase effects. Additionally, these effects should be presented in context with other activities in the area that produce measurable air quality effects.

For this example, the emissions estimates, both for the initial existing conditions and for the future year projections, were segregated into construction and operational activities

for both the city and the AFB. Emission estimates were compiled for five pollutants: carbon monoxide (CO), volatile organic compounds (VOCs), oxides of nitrogen (NO_x), sulfur oxides (SO_x), and particulates (PM_{10}). VOCs estimates were compiled as an ozone (O_3) indicator, while particulate lead was omitted due to its low level of concern within the subject area. Emissions from stationary sources were estimated using information found in *Compilation of Air Pollution Emission Factors (AP-42), Volume I, Stationary, Point, and Area Sources* (USEPA, 1995) and *Supplement B to Compilation of Air Pollution Emission Factors (AP-42), Volume I, Stationary, Point, and Area Sources* (USEPA, 1996).

Operational Activities -- Major Sources

Development of the cumulative emission estimate begins with the stationary source emission inventory for the federal facility. Incorporation of this existing document saves time and provides information on specific activities that may be useful as surrogate data for future activity emissions. A copy of the emission inventory for an AFB can be obtained from the air quality manager in the base environmental compliance office. For the base evaluated in this study, emission inventories were available for 1993 through 1996. However, discussions with the base air quality manager revealed that the earlier inventories overestimated emissions and therefore only the 1995 and 1996 data could be considered as accurate.

Major stationary source emissions for the city, or other federal facility, activities may be obtained either through the state air quality office or through the USEPA regional office. Depending on the level of detail requested on individual sources it may be necessary to process a Freedom of Information Act (FOIA) request to obtain the data. Some states,

however, maintain a separate document, or data file, containing summary emission data for each major source. This document, if available, can be obtained without a FOIA request. The information provided in the summary document used for this study provided both the actual and allowed emissions for each source and pollutant, and included sources where emission inventories had not been completed. Where no emission inventory had been completed and only the allowed emissions were reported, these allowed emissions were used in the development of the cumulative inventory. Also, the state summary only provided the most current data available. For example, if one source reported actual emissions for 1994, 1995, and 1996 and another for 1993 only, the summary report provided the 1996 emissions from the first source combined with the 1993 emissions from the second source. While this data may be inaccurate as to current emissions, it was the best information available.

Operational Activities -- Vehicles

One of the largest air emission source categories is vehicle operations. Since vehicles are mobile sources, they are not included in the base emission inventory or the state emission summary documents; therefore, separate estimates must be made for their inclusion. Emission factors for use in calculating CO, VOC, NO_x, and PM_{10} emissions are available in the *Compilation of Air Pollution Emission Factors (AP-42), Volume II: Mobile Sources* (USEPA, 1985) and *Supplement A to Compilation of Air Pollution Emission Factors (AP-42), Volume II: Mobile Sources* (USEPA, 1991). These emission factors are based on vehicle type and number of vehicle miles traveled (VMT). Therefore, to calculate the emissions for the vehicle use in a given area for a specific time period, the information requirements are: the VMT for the period of concern; the type and age of

vehicles used; and the fraction of the VMT that can be attributed to each vehicle type. AP-42 provides emission factor information for eight different vehicle types of various ages with multiple adjustment factors for such considerations as: percent cold start versus hot start; temperature and altitude variations; average speed; and potential for improper fuel use. Additionally, the road surface itself can be considered as a source for fugitive dust emissions resulting from vehicle traffic. PM_{10} estimations can be made to account for fugitive dust from both paved and unpaved road surfaces based on data and methods provided in AP-42.

The information collected during any given study may not be in the form necessary to conduct the calculations. For this study case, VMT and number of vehicles for the entire county (excluding the AFB) was obtained from the state Department of Transportation. No information was available regarding vehicle type and age. Population figures for the county and city from the growth trend report were used to determine the number of vehicles in the city by ratio to the city population. The national average age and type tables and emission sensitivity tables provided in AP-42 were used to account for the lack of specific vehicle fleet mix data. See Table D.14 for sample calculations of vehicle emissions using these methods and assumptions.

If the VMT is not readily available for the study area, such as for the test case AFB, it can be determined through an area traffic study. Traffic studies can be obtained from the base or city traffic engineer or planner for the relevant areas. In this case, a base traffic study was obtained for use in developing a VMT estimate. As discussed in Beaton et al. (1982), traffic counts at each roadway section of concern can be multiplied by the length of the roadway segment to determine the VMT for that segment. Adding the VMT for each segment provides the VMT data for the total area needed for the previously discussed

Table D.14: Sample Calculations for Annual Vehicle Emissions

1. Determine number of vehicles:

1996 - County Population = 125,239
- City Population = 102,790
- No. of vehicles registered in county = 112,848

125,239/112,848 = 1.11 persons/vehicle registered (county), therefore,

102,790/1.11 = 92604 vehicles in city

2. Determine VMT:

From Dept. of Trans., Daily Vehicle Miles (DVM) = 1,852,766 (county)

DVM/No. of vehicles = 1,852,766/112,848 = 16.42 miles/vehicle-day

16.42 x 92604 x 365 days = 555,001,177 VMT/year for the city

3. Calculate CO, VOC, and NO_x emissions:

Assumptions/Givens:
- Apply national average speed of 19.6 miles per hour
- Based on annual average temperature of 64° F, apply 75° F emission factors (EFs)
- Cold/Hot start VMT percentages = 20.6% cold start, 52.1% stabilized, and 27.3% hot start (Federal Test Procedure conditions)

Table data is given for average vehicle type and age mix in 1995, 2000, and 2010. Interpolate between given data to determine 1996-1999 factors and 2001-2009 factors

After interpolation, CO EF (1996) = 13.59 grams/mile
VOC EF (1996) = 1.20 grams/mile
NO_x EF (1996) = 1.60 grams/mile

1996 CO emission = CO EF x VMT = 7,542,465,995 g/yr or 16,631,138 lbs/yr

Similarly, 1996 VOC emission = 1,468,533 lbs/yr
1996 NO_x emission = 1,958,044 lbs/yr

Table D.14 (continued):

3. Calculate PM_{10} emissions from vehicles:

Assumptions/Givens:
- Apply AP-42 Light Duty Gasoline Vehicle (LDGV) age mix
- Use 75° F emission factors
- Apply AP-42 Jan 1 1988 VMT mix example to determine EF_{engine}
- EF_{brakes} = .0128 g/mi
- EF_{tires} = .002 g/mi
- EF_{engine} = .60 g/mi (pre-1987)
  = .20 g/mi (1987 and after)
- No leaded fuel used
- All PM is PM_{10}
- All vehicles are driven equal miles

From LDGV age mix, for 1996, 38.5% of vehicles are pre-1987, therefore

$$1996\ PM_{10} = (VMT \times EF_{brakes}) + (VMT \times EF_{tires}) + (.385 \times VMT \times EF_{engine\ (pre\text{-}1987)}) + (.615 \times VMT \times EF_{engine\ (1987\ and\ after)})$$

1996 vehicle PM_{10} = 451,329 lbs/yr

NOTE: Percentage of pre-1987 vehicles will change and must be determined for each successive year.

4. Calculate PM_{10} emissions from road surface fugitive dust:

Assumptions/Givens:
- Assume high average daily traffic (ADT) (> 5000 vehicles per day) conditions are applicable to all roads in the study area
- From AP-42, annual median silt loading (sL) = 0.4 g/m^2 (high ADT)
  = 2.5 g/m^2 (low ADT)
- Applicable vehicle weight range - (1.8 to 38 Megagrams)
- Assume 1.8 Megagrams is representative of typical traffic
- From AP-42, k = 7.3 g/VMT

Using the empirical equation:

$$E = k\,(sL/2)^{0.65}(W/3)^{1.5} = \text{the per VMT emission factor}$$

$$E = 7.3\,(0.4/2)^{0.65}(1.8/3)^{1.5} = 1.192 \text{ g/VMT}$$

1996 fugitive PM_{10} = 1,458,743 lbs/yr

calculations. See Table D.15 for a sample calculation of VMT for a roadway segment given intersection traffic counts. These methods for calculating vehicle based emissions are not the most precise of those available in AP-42. However, they are sufficiently accurate for long term projection and include the procedures stated to be appropriate for large areas and for the preparation of air quality modeling input information (USEPA, 1991).

Operational Activities -- Aircraft

Aircraft emissions are an important component of the cumulative inventory when there is major air traffic such as for an AFB with an active flight line or a city with a commercial airport. AP-42 provides emission factors for several aircraft types, however, the military listings are incomplete. Additional emission factor information for military aircraft can be found in *Calculation Methods for Criteria Air Pollutant Emission Inventories* by Jagielski and O'Brien (1994). AP-42 and Jagielski and O'Brien both describe the same method for developing emissions estimates from aircraft operations. One important consideration when developing the estimates is that aircraft engine maintenance and testing operations need to be included where appropriate. For the test case, the municipal airport is not a major hub and little if any maintenance is performed. For those aircraft activities only the landing-and-takeoff (LTO) cycles are included as mobile source contributions to the cumulative inventory. Table D.16 presents a sample calculation for the small municipal aircraft activity.

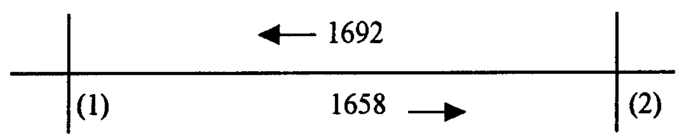
The AFB, however, conducts routine testing and maintenance of the aircraft operating from its flightline. Some of these activities such as aerospace ground equipment (AGE) emissions and jet engine test cell emissions are included in the base emissions

Table D.15: Sample Calculations for Determining VMT from Traffic Counts

Traffic count information can be presented in several formats. This example will demonstrate VMT calculation from 2 typical traffic count presentation styles.

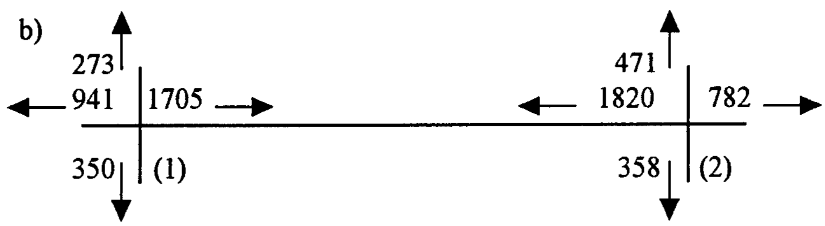
The following information should be provided in the traffic study for each major roadway segment and intersection (numbers given are 24 hr traffic counts):

a)



or

b)



If the segment between the two intersections is 0.6 miles long then the VMT is calculated as follows:

for a)

$$(1692 \times 0.6) + (1658 \times 0.6) = 2010 \text{ mi/day}$$

$$2010 \text{ mi/day} \times 365 \text{ days} = 733{,}650 \text{ VMT/yr}$$

for b)

$$\text{Daily miles} = \frac{\text{Vehicles Entering Intersection (1)} + \text{Vehicles Leaving Int.}_{\text{not along segment}} \text{(1)}}{2}$$

$$+ \frac{\text{Vehicles Entering Intersection (2)} + \text{Vehicles Leaving Int.}_{\text{not along segment}} \text{(2)}}{2}$$

$$= \frac{1820 + 273 + 941 + 350}{2} + \frac{1705 + 471 + 782 + 358}{2} = 3350 \text{ vehicles/day}$$

Table D.15 (continued):

Annual VMT = 3350 vehicles/day x 0.6 miles x 365 days/yr = 733,650 mi/yr

The total VMT for the study area is then determined by summing the VMTs determined for each segment.

NOTES:

1. The AFB traffic study provided information in format a).
2. Traffic studies are typically conducted during a 5-day work week and do not account for reduced traffic on weekends. However, this is not considered to create a significant increase in the VMT estimate since it is also offset by lack of vehicle use data on minor road segments.

Table D.16: Sample Calculations for Municipal Aircraft Emissions

Assumptions/Givens:
- 59,000 passengers are reported to be serviced by the airport annually
- All aircraft are in the 15-32 passenger range
- Assume all aircraft emissions are representative of 2 GE turboprop TPE 331-3 engines
- Assume all PM is PM_{10}
- LTO cycle times for large congested airports are applicable for the test case since the base and municipal flight activities are co-located (same runways used). Otherwise, obtain LTO cycle times applicable to the individual situation by contacting the airport operations office

1. Estimate annual sorties (if not provided by airport operations office)

Average passenger load = (15+32)/2 = 23.5 ≅ 24

Annual sorties = 59000/24 = 2458 sorties per year or 6 -7 sorties per day
1 sortie = 1 LTO cycle

2. Calculate emissions from LTO cycles

From AP-42:

Procedure	Power Setting	Hrs/Procedure	CO	VOC	NO_x	SO_x	PM
			EFs (lbs/hr)				
Taxi/Idle (out)	Idle	0.317	6.89	8.86	0.32	0.11	0.3
Takeoff	100%	0.0083	0.35	0.05	5.66	0.46	0.8
Climbout	90%	0.042	0.40	0.06	4.85	0.41	0.6
Approach	30%	0.075	1.74	0.16	2.48	0.25	0.6
Taxi/Idle (in)	Idle	0.117	6.89	8.86	0.32	0.11	0.3

CO emissions = [(.317 x 6.89) + (.0083 x 0.35) + (.042 x 0.40) + (.075 x 1.74) + (.117 x 6.89)] x 2 engines/sortie x 2458 sorties = 15438 lbs/yr

VOC emissions = [(.317 x 8.86) + (.0083 x 0.05) + (.042 x 0.06) + (.075 x 0.16) + (.117 x 8.86)] x 2 engines/sortie x 2458 sorties = 18977 lbs/yr

NO_x emissions = [(.317 x 0.32) + (.0083 x 5.66) + (.042 x 4.85) + (.075 x 2.48) + (.117 x 0.32)] x 2 engines/sortie x 2458 sorties = 2821 lbs/yr

SO_x emissions = [(.317 x 0.11) + (.0083 x 0.46) + (.042 x 0.41) + (.075 x 0.25) + (.117 x 0.11)] x 2 engines/sortie x 2458 sorties = 430 lbs/yr

PM emissions = [(.317 x 0.3) + (.0083 x 0.8) + (.042 x 0.6) + (.075 x 0.6) + (.117 x 0.3)] x 2 engines/sortie x 2458 sorties = 430 lbs/yr

inventory and, therefore, did not require separate calculations. Jagielski and O'Brien (1994) present simple methods for estimating these emissions if they are not already available. An additional maintenance activity that is not accounted for in the base emission inventory is the conduct of aircraft trim operations. A trim operation is where the engine power output levels are evaluated while the aircraft is held stationary. This activity differs from jet engine test cell operations in that the engine is not removed from the airframe. The calculation of LTOs is conducted in the same manner as for civilian aircraft with the appropriate emission factors and operating times for each specific engine. Additionally, Air Force training activities can include considerable emissions from touch-and-go (T&G) activities. Information such as the type and number of aircraft used at a base, the number of LTO and T&G operations conducted annually by each aircraft type, and the percentage of training versus operational sorties flown can be obtained from the base operations flight. Aircraft maintenance personnel can be contacted to obtain trim operation statistics. Sample calculations for military aircraft mobile emissions are presented in Table D.17.

Operational Activities -- Other Sources

Other common operational activities where emission estimates can be conducted with reasonable ease and accuracy include: small engine use (e.g. lawnmowers); natural gas combustion emissions from non-permitted furnaces and boilers; and non-regulated fugitive VOC emissions from commercial and consumer activity. Except for natural gas combustion, emissions from these activities can be estimated using population and growth projection information. AP-42 provides a per capita based emission factor for estimating the area wide commercial and consumer solvent use VOC emissions. The solvent categories

Table D.17: Sample Calculations for Military Aircraft Emissions

Assumptions/Givens:
- An average of 2 trim operations are conducted per aircraft annually
- Trim = 40 min idle, 1 min intermediate, 5 min military, 1.5 min afterburner (AB)
  (or, for aircraft without AB capability)
  Trim = 40 min idle, 1 min approach, 5 min intermediate, 1.5 min military
- Assume all PM is PM_{10}
- 87% of all sorties are training sorties
- Training sorties average 6 T&Gs per LTO
- Base has 90 T-38 aircraft and 19 AT-38 aircraft (2 engines each)
- Annual T-38 sorties = 34,650
- Annual AT-38 sorties = 5,585

1. Calculate emissions from LTO cycles

From Jagielski and O'Brien: J85-5A EFs (lbs/hr)

Procedure	Power Setting	Hrs/Procedure	CO	VOC	NO_x	SO_x	PM
Taxi/Idle (out)	Idle	0.213	80.1	13.5	0.59	0.45	0.01
Takeoff	AB	0.007	216.32	0.58	16.64	8.32	0.07
Climbout	Military	0.015	76.27	2.1	6.84	2.63	0.05
Approach	Intermediate	0.063	62.78	5.11	3.36	1.46	0.02
Taxi/Idle (in)	Idle	0.107	80.1	13.5	0.59	0.45	0.01

T-38 and AT-38 aircraft are identical for emission estimation purposes (total = 109).

Using the same method as shown for municipal aircraft LTO cycles:

CO emissions = 2,594,790 lbs/yr

VOC emissions = 376,398 lbs/yr

NO_x emissions = 49,856 lbs/yr

SO_x emissions = 26,850 lbs/yr

PM emissions = 459 lbs/yr

Table D.17(continued):

2. Calculate emissions from T&G cycles

No. of T&Gs = (34650 sorties + 5585 sorties) x .87 x 6 T&G/sortie = 210,027 T&Gs/yr

Calculate T&G emissions using power setting, hrs/procedure, and emission factor data from LTO calculations for Procedures Takeoff, Climbout, and Approach only (omit Taxi in/out).

For example, CO emissions = [(.007 x 216.32) + (.015 x 76.27) + (.063 x 62.78)]
x 2 engines/sortie x 210,027 T&Gs = 2,777,998 lbs/yr

Similarly,

VOC emissions = 150,165 lbs/yr

NO_x emissions = 180,943 lbs/yr

SO_x emissions = 79,672 lbs/yr

PM emissions = 1050 lbs/yr

NOTE: Base operations may provide separate hrs/procedure data for T&Gs than for LTOs. Use base specific information when available.

3. Calculate emissions from trim operations

		J85-5A EFs (lbs/hr)				
Power Setting	Hrs/Procedure	CO	VOC	NO_x	SO_x	PM
Idle	0.667	80.1	13.5	0.59	0.45	0.01
Intermediate	0.017	62.78	5.11	3.36	1.46	0.02
Military	0.083	76.27	2.1	6.84	2.63	0.05
AB	0.025	216.32	0.58	16.64	8.32	0.07

CO emissions = [(.667 x 80.1) + (.017 x 62.78) + (.083 x 76.27) + (.025 x 216.32)]
x 109 aircraft x 2 engines/aircraft x 2 trims/yr = 28,877 lbs/yr

Similarly,

VOC emissions = 4,046 lbs/yr

NO_x emissions = 625 lbs/yr

SO_x emissions = 328 lbs/yr

PM emissions = 6 lbs/yr

4. Sum LTO, T&G, and Trim emissions to obtain total aircraft operational emissions.

covered include: aerosol products, household products, toiletries, rubbing compounds, windshield washing, polishes and waxes, non-industrial adhesives, space deodorants, moth control, and laundry detergents. Additional emission factor information is provided for VOC estimates related to non-industrial surface coating activities such as architectural painting and automotive refinishing.

Natural gas (NG) use combustive emissions were calculated both for the entire city area and for individual construction and demolition projects. NG use varies between regions in the United States; therefore, local consumption information is critical to accurate emission estimates. Information on the total NG consumed in an area can be obtained from local gas company records. Information on the total NG use at the AFB can be obtained from utility records maintained by the Civil Engineer Squadron and emission information maintained by the air quality manager. Table D.18 presents sample calculations for estimating emissions from each of these source categories.

There is potential for inaccuracy within the assumptions made for these estimates. These potential inaccuracies are acceptable, however, as long as the assessors and the decision makers are aware of them. NG use estimates for the city, provided by the local gas company, have been adjusted to account for the portion of the total quantity used by the base. Emissions from the base residential activities are presented in a separate calculation (similar to the city residential use calculation) and the base operation activity NG combustion emissions are accounted for in the stationary source emission inventory. However, a similar adjustment was not made for the city's major sources whose emissions are listed on the state summary emission inventory. These sources were contacted but information was not obtainable for inclusion in this study. Therefore, the NG use

Table D.18: Sample Calculations for Operational Activities - Other Source Categories

Assumptions/Givens:
- 1996 city population = 102,790
- Per Capita EFs from AP-42:
  Commercial/Consumer Solvent Use = 9.2 lb/yr Non-Methane VOCs
  Non-Industrial Surface Coating
  -- Architectural = 4.6 lbs/yr VOCs
  -- Automotive Refinishing = 1.9 lbs/yr VOCs
- 1996 city dwelling units = 41259
- 1996 base dwelling units = 1288
- Assume PM is PM_{10}
- Assume 1 4-stroke engine (lawnmower) per dwelling unit

1. Calculate Commercial/Consumer Solvent Use Emissions

1996 VOC emissions = 102,790 people x 9.2 lbs/yr = 945,688 lbs

2. Calculate Non-Industrial Surface Coating Emissions

1996 architectural emissions = 102,790 people x 4.6 lbs/yr = 472,834 lbs VOC

1996 automotive refinishing emissions = 102,790 people x 1.9 lbs/yr = 195,301 lbs VOC

3. Calculate 4-Stroke Engine Emissions

From AP-42, EFs for 4-stroke lawn and garden engines in grams/year (assuming annual usage of 50 hrs at 40% load factor) are:

CO	VOC (exhaust & evaporative)	NO_x	SO_x	PM
19,100	1703	217	26	31

CO

1996 city CO emissions = 19100 x 41259 = 788,046,900 g or 1,737,643 lbs
1996 base CO emissions = 19100 x 1288 = 24,600,800 g or 54,245 lbs

Similar calculations can be made for the other pollutants

Table D.18 (continued):

4. Calculate area natural gas (NG) use combustive emissions

- Residential/Commercial NG use split for the AFB was determined from base records to be 25% residential use and 75% commercial use.
- Assume the same ratio can be applied to the city.
- 1996 base NG use = 428,765,000 SCF
- 1996 city NG use (w/o base) ≅ 5,000,000,000 SCF
- Boiler/Furnace EFs from AP-42:

	EFs (lb/MM SCF)				
< 0.3 MM BTU/hr	CO	VOC	NO_x	SO_x	PM_{10}
	40	11	94	0.6	11.18
0.3 - < 10 MM BTU/hr	CO	VOC	NO_x	SO_x	PM_{10}
	21	8	100	0.6	12

1996 base residential emissions (assume residential furnaces & boilers < 0.3 MM BTU/hr)

CO emissions = [(428,765,000 x .25)/1,000,000] x 40 = 4288 lbs
VOC emissions = [(428,765,000 x .25)/1,000,000] x 11 = 1179 lbs
NO_x emissions = [(428,765,000 x .25)/1,000,000] x 94 = 10076 lbs
SO_x emissions = [(428,765,000 x .25)/1,000,000] x 0.6 = 64 lbs
PM_{10} emissions = [(428,765,000 x .25)/1,000,000] x 11.18 = 1198 lbs

1996 city residential emissions (assume residential furnaces & boilers < 0.3 MM BTU/hr)

CO emissions = [(5,000,000,000 x .25)/1,000,000] x 40 = 50,000 lbs
VOC emissions = [(5,000,000,000 x .25)/1,000,000] x 11 = 13,750 lbs
NO_x emissions = [(5,000,000,000 x .25)/1,000,000] x 94 = 117,500 lbs
SO_x emissions = [(5,000,000,000 x .25)/1,000,000] x 0.6 = 750 lbs
PM_{10} emissions = [(5,000,000,000 x .25)/1,000,000] x 11.18 = 13,975 lbs

1996 city commercial emissions (assume commercial furnaces/boilers 0.3-<10 MMBTU/hr)

CO emissions = [(5,000,000,000 x .75)/1,000,000] x 21 = 78,750 lbs
VOC emissions = [(5,000,000,000 x .75)/1,000,000] x 8 = 30,000 lbs
NO_x emissions = [(5,000,000,000 x .75)/1,000,000] x 100 = 375,000 lbs
SO_x emissions = [(5,000,000,000 x .75)/1,000,000] x 0.6 = 2,250 lbs
PM_{10} emissions = [(5,000,000,000 x .75)/1,000,000] x 12 = 45,000 lbs

combustive emissions for these sources are accounted for twice: in the emission inventory summary report; and in the overall city use calculation.

Estimations made for 4-stroke engine emissions assume that every dwelling has the national average lawn mower work load. This implies that each dwelling has a lawn to maintain. In reality, apartment complexes do not require the same level of lawn care per dwelling unit as single family homes. Also, the assumption is made that each dwelling unit has one, and only one, 4-stroke lawn and garden engine. AP-42 Volume 1 (USEPA, 1995) also provides emission factor information on 2-stroke lawn and garden engines and 4-stroke miscellaneous engines. It is likely that these other engine types are operated at some residential or commercial locations.

Operational Activities -- Estimates Not Included

Careful analysis of the operational source emission estimates conducted reveals that several sources are, or appear to be, unaccounted for. Sources that were not included due to lack of data include city-wide food preparation activities at restaurants and evaporative fuel losses from residential and off-base commercial fuel dispensing activities. On-base fuel dispensing activities are accounted for in the base emission inventory. Other activities were included indirectly. Activities that were indirectly included in the estimate are landfill operations and waste water treatment plant operations.

The primary emission of concern from landfill operations (without off-gas control) is fugitive VOC. The primary air pollutants from municipal waste water treatment plants are methane and non-methane VOCs. The National Ambient Air Quality Standard (NAAQS) for hydrocarbons is based on consideration of non-methane hydrocarbons only,

therefore the methane emissions are beyond the scope of this analysis. The non-methane VOC emissions from both source categories are indirectly accounted for in the area-wide commercial and consumer solvent use emissions estimates since this estimating procedure considers complete volatilization of the hydrocarbons from the products in use. This would include any VOC emissions released from the products after disposal to either facility.

One additional omission from this inventory that should be considered when compiling a cumulative emission inventory for an area are the emissions from electrical power generation. This category was not included for this example because the power plant is located in a neighboring county -- well outside the defined spatial boundaries. If this were not the case, emission information would be included in the emission inventory summary documents or could be estimated using information obtained from the utility company and AP-42.

Construction Activities -- Source Categories

Typically, a NEPA analysis deals with the emissions resulting from new activities. These emissions are evaluated for both the construction and operation stages of a project and, occasionally, for the demolition stage. In a cumulative sense, construction, operation, and demolition phase emissions should be included for all activities within the spatial and temporal boundaries. The previously discussed operational emission estimates provide the operational stage emissions for the activities initiated prior to the study timeframe (e.g., the baseline emissions). The following subsections will summarize the development of emission estimates for the construction and operation phases of the RFFAs as well as the demolition phase emissions of any current activities that are anticipated to cease within the study

timeframe. The categories of projects evaluated include: water systems, sanitary sewer systems, storm drains, NG distribution systems, electrical distribution systems, facility disposals, pavements construction and repair, facility construction, roofing construction and repair, and housing development.

Construction Activities -- General Activity Emissions

Emissions from construction activities can be either estimated directly through the application of AP-42 emission factors or by applying surrogate information from other, similar construction activities. The main air pollution sources from general construction activities estimated for this analysis are fugitive dust emissions and combustive emissions from construction vehicles and equipment. AP-42 provides information on the development of construction combustive activity emissions. However, to apply the emission factors given, it is necessary to estimate the specific construction activities conducted for each project. An alternative method is to apply the emissions estimates generated at a surrogate site where similar, general urban-scale development activities have been conducted. Construction combustive pound-per-acre emission factors for general construction activities have been developed relative to community development plan impact assessments and applied to multiple U.S. Air Force environmental assessments and impact statements.

Application of these average combustive source construction emission estimates is possibly the most imprecise technique applied to this analysis. Why, then, should such an arbitrary estimate be applied to specific construction RFFAs? Two reasons can be offered. The first is that, since this method is commonly used in Air Force generated NEPA documents to predict direct project effects, use of the same estimating procedure for

cumulative issues provides common ground for emission comparisons with direct effect estimates. The second reason is that application of the specific construction activity emission factors found in AP-42 require detailed knowledge about the project proposal. Estimates are needed regarding such details as the type of construction equipment used (e.g. bulldozers, dump trucks, cranes, etc.) and the number of hours each piece of equipment will be in operation. Determination of such detail for each proposal is time consuming and, given the level of detail known about each proposal, may require so many subjective estimates as to be no more accurate than the generic estimating factor. Table D.19 presents the per-acre emission factors which were developed from a medium-scale community development plan for the complete demolition and re-development of the planned acreage.

AP-42 states that fugitive particulate matter resulting from construction activity soil disturbance can be estimated on a per-acre basis. Particulate matter emissions from ground disturbing activities are estimated at 110 pounds per acre per day (USEPA, 1995). Multiple Air Force EISs where this emission factor has been applied have also assumed that, since this estimate is for total suspended particulates (TSP), a reasonable PM_{10} estimate would be 50% or 55 pounds per acre per day. It is further assumed in these studies that construction activities average 4 acre-days per acre of disturbance. Therefore, a PM_{10} estimate can be made for construction fugitive dust with the following equation (Department of the Air Force, 1994):

$$PM_{10}\ \text{(lbs/yr)} = \text{(4 acre-days/acre)} \times \text{(55 lbs/acre-day)} \times \text{(acres/yr)}$$

Typical facilities constructed for Air Force include utilities and climate control for personnel comfort. Operational emissions from the constructed facility can be estimated from the NG usage. Individual facility NG use can be determined at the AFB from utility

Table D.19: Air Force Construction Combustion Emission Factors (after Department of the Air Force, 1994)

Pollutant	Pounds per Acre
CO	3,820
VOC	290
NO_x	1,095
SO_x	100
PM_{10}	85

records maintained by the Civil Engineer Squadron and emission information maintained by the air quality manager. From this information, it was determined that for older facilities, approximately 50 cubic feet (CF) of NG is consumed annually per square foot (SF) of facility. For newer facilities, the ratio is approximately 40 CF annually per SF. A caution is that the NG use is linked to the local climate. This data is relevant to this study area only. Table D.20 presents sample calculations for the development of construction emissions for typical Air Force development projects. If electrical power use emission estimates resulting from the increased demand on the generating facility are desired, a similar SF ratio can be determined from existing facility records combined with emission data from the power plant.

Construction Activities -- Specific Activity Emissions

Activity specific construction or subsequent operational emissions for certain types of projects were based on AP-42 factors for the project (e.g., paint booth operations) or surrogate information from existing, similar activities. For example, emission inventory information from the test case AFB noted an operational emission of 34 lbs/yr PM_{10} from a fighter jet paint stripping facility utilizing 11,000 lbs of bead material per year. This information was applied to the operational emissions of proposed facilities of similar scale. Demolition activities generate dust emissions, construction equipment combustion emissions, and reduced natural gas combustion emissions resulting from cessation of use. For this study, construction equipment combustion emissions were considered to be accounted for in the general construction estimates for new facilities. This was done because the information on new facility construction projects identified the same facilities for demolition that were listed separately in the base demolition program. Also, standard practice at Air Force bases

Table D.20: Sample Calculations for General Construction Activity Emissions

<u>Available Project Information</u>

Project is to construct a 330,000 square-foot training facility with high-bay areas for fighters and large aircraft, classrooms, laboratories and support space. This facility will accommodate training courses for: aircraft maintenance officer, crew chief, loadmaster, quality assurance, technical order, analysis, training activities as well as course scheduling activities. It will also include space for specialty trainers, consolidated toolkit rooms, technical order rooms, auditorium, contractor maintenance area, squadron command section, and a computer local area network. Project is scheduled for construction in 2003.

Assumptions:
- Construction emissions based on fugitive dust and combustive sources.
- Operation emissions based on natural gas consumption estimated at 40 SCF/SF-YR
- All construction emissions occur in 2003
- Operational emissions begin in 2004
- Standing seam metal roof, exterior finish combination of metal siding (surface coating applied prior to material delivery) and split-face block in accordance with architectural guidelines found in base development plan

1. Calculate Construction Emissions

330,000/43560 = 7.6 acres of surface area demolished and re-developed

From emission factors presented in Table D.19:

Combustive Construction Emissions are:

7.6 acres x 3820 lbs/acre = 29,032 lbs CO
7.6 acres x 290 lbs/acre = 2204 lbs VOC
7.6 acres x 1095 lbs/acre = 8322 lbs NO_x
7.6 acres x 100 lbs/acre = 760 lbs SO_x
7.6 acres x 85 lbs/acre = 646 lbs PM_{10}

Fugitive Dust Emissions are:

7.6 acres/yr x 4 acre-days/acre x 55 lbs/acre-day = 1672 lbs PM_{10}

Total PM_{10} construction emissions = 1672 + 646 = 2318 lbs

Table D.20 (continued):

2. Calculate Operational Emissions

Using emission factors for 0.3 - < 10 MM BTU/hr size furnaces and boilers and assuming entire facility is climate controlled:

330,000 sq ft x 40 SCF/SF = 13,200,000 SCF of NG per year

CO = 13,200,000 x (21 lbs/1,000,000 SCF) = 277 lbs/yr

Similarly,

VOC = 106 lbs/yr
NO_x = 1320 lbs/yr
SO_x = 8 lbs/yr
PM_{10} = 158 lbs/yr

is to attempt to sell the unwanted facility intact and move it to an off-base location. Failing this option, a base will employ wet suppression as an emission control strategy during demolition. As a result, fugitive dust emissions from demolition activities were not significantly quantifiable. Emissions reductions from the cessation of use of natural gas in associated furnaces and boilers were made using the locally determined use of 50 SCF of NG per square foot of facility. Other development activities required emission estimates specific to the construction materials used; examples included VOC emission estimates from asphalt paving and built-up roofing activities.

Construction Activities -- Pavements

Paving activities identified within the spatial and temporal boundaries included: asphalt or concrete pavement construction and repair, and runway striping. Striping emission estimates can be made through a simple estimation of the volume of paint used multiplied by the paint-specific VOC emission factors provided in AP-42. Concrete construction (entire existing roadway demolished and re-built) was estimated with the per-acre emission factors for fugitive dust and combustion sources as described for general construction activities. Concrete repair projects, identified where the entire roadway was not to be demolished and re-built, were estimated similar to the concrete construction projects except that the assumption was made that only 25% of the roadway would be demolished and rebuilt. The reasoning for this assumption was that if more than 25% of a road segment (e.g., paved area between two intersections) had failed, that segment would be identified for a complete re-build.

Asphalt paving projects were also segregated into repair and complete re-construction. If a road segment was to be repaired, emission estimates were based on the application of the asphalt overlay. For complete re-builds, asphalt emissions were combined with combustion emissions as described for concrete construction (AP-42 includes a section -- Section 4.5 -- on estimating emissions from asphalt paving operations).

Asphalt pavement is composed of compacted aggregate and an asphalt binder. Typical asphalt binders include asphalt cement and two forms of liquefied asphalt: asphalt cutbacks and asphalt emulsions. The primary emissions from these materials are VOCs. Of the three types, cutback asphalt is the primary emission source. However, minor amounts are emitted from asphalt cements and emulsions. Liquefied asphalts are used in tack-and seal operation, roadbed priming for hot-mix asphalt concrete application, and as the primary binder for small paving operations. Large paving activities typically rely on hot-mix asphalt concrete which is created by heating asphalt cement and combining it with the aggregate (USEPA, 1995).

Prior to estimating emissions, it was necessary to first determine the size of the area to be paved and the type of asphalt used for tack and prime coatings. Pavement project areas were estimated based on brief statements of the project scope, from traffic studies and comprehensive planning documents, and available city and base maps. For this study, it was determined that hot-mix asphalt concrete was used for all AFB applications. Further, since the AFB and the city use the same local area pavement contractor, the assumption was made that asphalt emulsions would also be used for city projects. To account for liquefied asphalts, it was assumed that one coat of liquefied asphalt was applied to the entire area of

each asphalt paving project. As with all other construction estimates, adjustments can be made as more information becomes available.

AP-42 emission factors were used for estimating long-term emissions from cutback asphalt applications (see Table D.21). Asphalt cutbacks are mixtures of asphalt cement with volatile petroleum distillates that thin, or "cutback," the asphalt cement. The petroleum distillate, referred to as diluent, is the primary source of the VOC emissions. While some VOCs are released during the mixing operation at the plant, the majority of the VOCs are released from the road surface over the first three to four months after construction (USEPA, 1995). These emissions result from the curing process where the liquefied asphalt returns to its solid form. AP-42 does not, however, provide emission factor information regarding asphalt emulsion emissions. Emulsified asphalts consist of asphalt cement suspended in water containing an emulsifier. This petroleum distillate substitute is approximately 98% water and 2% emulsifier. Based on a diluent content average of 35%, emulsifier substitution reduces VOC emissions by 0.078 lb/lb of slow cure asphalt, 0.209 lb/lb of medium cure asphalt, and 0.204 lb/lb of rapid cure asphalt (Markwordt and Bunyard, 1977). Using this information, the lb/lb emission factors presented in AP-42 for cutback asphalt were modified for asphalt emulsions. The resultant emissions calculated were from the asphalt itself, rather than the evaporation of the thinning agent. Table D.22 presents a sample calculation for estimating VOC emissions from newly constructed asphalt pavements using asphalt emulsions.

Table D.21: Percent of Cutback Asphalt Evaporated as VOC (after USEPA, 1995)

	Percent Diluent in Cutback Asphalt (by vol.)		
Cutback Cure Rate	25%	35%	45%
Rapid Cure (RC)	17% (by wt.)	24% (by wt.)	32% (by wt.)
Medium Cure (MC)	14% (by wt.)	20% (by wt.)	26% (by wt.)
Slow Cure (SC)	5% (by wt.)	8% (by wt.)	10% (by wt.)

Table D.22: Sample Calculations for Pavement Construction Activity Emissions

<u>Available Project Information</u>

Project is to resurface an existing asphalt road segment between two identified intersections. Project will also align one of these existing intersections where the two lateral roads currently intersect the project road with an offset of approximately 60 feet. Additionally, a new left turn lane will be constructed for the newly aligned intersection. Project is scheduled for FY96, therefore the construction emissions will be applied to CY97.

Assumptions/Givens:
- Construction emissions based on fugitive dust and combustive sources.
- From Table D.21, rapid cure (RC) cutback asphalt with 35% diluent emits 0.24 lbs VOC/lb asphalt
- Assume prime/tack coat quantity can be estimated as one coat over entire project pavement area

1. Calculate Construction Emissions

From transportation development map provided by the city, approximately 4.3 acres will be demolished and reconstructed.

From emission factors presented in Table D.19:

Combustive Construction Emissions are:

4.3 acres x 3820 lbs/acre = 16426 lbs CO
4.3 acres x 290 lbs/acre = 1247 lbs VOC
4.3 acres x 1095 lbs/acre = 4709 lbs NO_x
4.3 acres x 100 lbs/acre = 430 lbs SO_x
4.3 acres x 85 lbs/acre = 366 lbs PM_{10}

Fugitive Dust Emissions are:

4.3 acres/yr x 4 acre-days/acre x 55 lbs/acre-day = 946 lbs PM_{10}

Total PM_{10} construction emissions = 366 + 946 = 1312 lbs

Table D.22 (continued):

2. Calculate Asphalt Pavement Evaporative Emissions Emulsion substitution reduces RC emissions by 0.204 lb VOC/lb asphalt, therefore 0.24 lb/lb - 0.204 lb/lb = 0.036 lb VOC/lb asphalt emulsion From Lapinski (1978), liquefied asphalt coatings are applied at an average of 0.33gal/sq yd From Pulver (1969) liquefied asphalt weights approximately 9.5 lbs/gal From transportation plan information and map, total area to be paved is estimated at 20800 sq yds (20800 sq yds) x (0.33 gal/sq yd) x (9.5 lbs/gal) x (0.036 lb/lb) = 2348 lbs VOC

Construction Activities -- Built-Up Roofing

AP-42 also addresses VOC emissions resulting from the production of asphalt roofing materials. However, it does not specifically address emissions resulting from construction activities using these materials. In this case, the roof construction activity of concern is composition, or "built-up," roofing. This type of roofing system is typically installed on a flat roof. It typically consists of two to five layers of asphalt saturated roofing felt alternated with coats of tar or asphalt and a final layer of gravel surfacing (Pulver, 1969). Emissions estimates for this activity consist of VOC estimates from the asphalt or tar coatings. Projects were identified for the repair of existing facility built-up roofs. For repairs, it was assumed that one additional felt layer would be added to the entire roof area. The emission factor developed previously for asphalt emulsions was applied to these calculations as shown in Table D.23.

Annual Summaries

Once the emissions estimates are conducted for the operational and construction activities within the spatial and temporal boundaries, the cumulative emission estimates should be organized into chronological sequence. Annual summary periods were selected for application to the analysis based on the level of detail of information provided. Base and city activity stationary source emission inventory data is presented on a annual basis. No information was available with respect to the specific time of year of emissions release. Project proposal information collected was categorized by either calendar or fiscal year. For calendar year (CY) based proposals, it was assumed that all construction emissions could be applied to the CY in which the project was scheduled. Operational emissions resulting from

Table D.23: Sample Calculations for Built-Up Roofing Construction Emissions

Available Project Information

Project is to repair the built-up roof on the Army Air Force Exchange Service (AAFES) main exchange facility. A scale drawing of base facilities allowed for the determination that the total roof area over the facility is 75,600 square feet. One layer of felt requires one layer of tack coat for adhesion to the existing roof surface plus one additional top layer of tack coat with embedded gravel for the new surface.

From Pulver (1969), the average application rate for one layer of tack coat is 40 lbs per square (1 square = 100 sq ft)

Assuming asphalt emulsion tack coat is used, from the previous example, the emission factor would be 0.036 lb VOC/lb asphalt emulsion.

Therefore,

(75,600 sq ft/100 sq ft) x 40 lbs/square x 2 coats x 0.036 lb/lb = 2,117 lbs VOC

those proposals were applied in the year immediately following the construction year and every year thereafter for the remainder of the study period. Fiscal year projections are linked to budgetary allotments. The U.S. federal government fiscal year (FY) begins on October 1 and ends on September 30. For example, FY98 begins October 1, 1997 and runs through September 30, 1998. Typically, funding for projects is not released to bases until the second quarter of the FY (e.g. January - March 1998). Due to time requirements for bid solicitation, contract award, and material delivery and staging, construction emissions resulting from FY projected proposals were applied to the CY after the FY (e.g. FY97 project construction emissions in CY98). The resulting operational emissions would be applied in the same manner as for CY proposals. Tables D.24 through D.33 present the annual summaries calculated for the study area for 1996 through 2005.

STEP 6 -- DETERMINING THE CHANGE IN AIR QUALITY

Once the cumulative emissions have been estimated and summarized within the pre-determined boundaries, the change to the background conditions should be evaluated. There are two main options for the effect analysis: evaluation of emission levels, and evaluation of ambient concentrations. Which approach to take is left to individual preference and the availability of background data.

Emission Levels

Given the emissions estimates from Step 6, the fastest, and simplest, analysis approach is to evaluate the emission level changes anticipated from the proposed activities. Parameters that can be obtained from this level of analysis include comparisons of the base

Table D.24: 1996 Emissions Summary in the Defined Spatial Boundaries

AFB Operation Sources					
	CO (lbs)	VOC (lbs)	NOx (lbs)	SOx (lbs)	PM10(lbs)
Vehicles	694625	73682	60142	0	49146
T-37 Trim	8707	1106	179	88	32
T-37 LTO	536585	53459	18974	7397	1522
T-37 T&G	1071909	24338	77796	25268	402
T-38/AT-38 Trim	28877	4046	625	328	6
T-38/AT-38 LTO	2269369	329192	43603	23483	401
T-38/AT-38 T&G	2429602	131333	158250	69680	918
Emission Inventory	53614	162044	66252	25571	19135
4-Stroke Engines	54245	4837	616	74	88
Residential NG Use	4288	1179	10076	64	1198
Sub-Total (lbs)	**7151821**	**785216**	**436513**	**151953**	**72848**
AFB Construction Sources					
Water System	1910	145	548	50	153
Electrical System	6112	464	1752	160	488
New Construction	1070	81	307	28	85
Pavements	76591	15057	21955	2005	6115
Roofing	0	3136	0	0	0
Sub-Total (lbs)	**85683**	**18883**	**24562**	**2243**	**6841**
AFB Total (tons)	**3619**	**402**	**231**	**77**	**40**
City Operations Sources					
Vehicles	16631138	1468533	1958044	0	1910072
Commuter Aircraft	15438	18976	2821	430	1017
Emission Summary	3000687	485947	12650020	1482456	418526
4-Stroke Engines	1737643	154932	19742	2365	2820
Comm/Consum VOC	0	1613803	0	0	0
Comm/Res NG Use	128750	43750	492500	3000	58975
Sub-Total (lbs)	**21513656**	**3785941**	**15123127**	**1488251**	**2391410**
City Construction Sources					
Pavements	109061	78644	31262	2855	8708
Sub-Total (lbs)	**109061**	**78644**	**31262**	**2855**	**8708**
City Total (tons)	**10811**	**1932**	**7577**	**746**	**1200**

Table D.25: 1997 Emissions Summary in the Defined Spatial Boundaries

	CO (lbs)	VOC (lbs)	NOx (lbs)	SOx (lbs)	PM10(lbs)
AFB Operation Sources					
Vehicles	645189	73682	60142	0	48491
T-37 Trim	8707	1106	179	88	32
T-37 LTO	557919	55584	19541	7691	1582
T-37 T&G	1114531	25306	80890	26272	418
T-38/AT-38 Trim	28877	4046	625	328	6
T-38/AT-38 LTO	2594790	376398	49856	26850	459
T-38/AT-38 T&G	2777998	150165	180942	79672	1050
Emission Inventory	53614	162044	66252	25571	19135
Const Related Ops	10	4	48	0	6
4-Stroke Engines	54245	4837	616	74	88
Residential NG Use	4288	1179	10076	64	1198
Sub-Total (lbs)	**7840168**	**854351**	**469167**	**166610**	**72465**
AFB Construction Sources					
Sewer System	8786	667	2519	230	702
Storm Drain	67232	5104	19272	1760	5368
NG System	4584	348	1314	120	366
Electrical System	2292	174	657	60	183
New Construction	38	3	11	1	3
Pavements	174880	17294	50129	4578	13963
Roofing	0	130	0	0	0
Key/MILCON	27733	2105	7950	726	2214
Sub-Total (lbs)	**285545**	**25825**	**81852**	**7475**	**22799**
AFB Total (tons)	**4063**	**440**	**276**	**87**	**48**
City Operations Sources					
Vehicles	15978563	1409873	1916933	0	1904566
Commuter Aircraft	15438	18976	2821	430	1017
Emission Summary	3000687	485947	12650020	1482456	418526
4-Stroke Engines	1743582	155462	19809	2373	2830
Comm/Consum VOC	0	1630885	0	0	0
Comm/Res NG Use	128750	43750	492500	3000	58975
Sub-Total (lbs)	**20867020**	**3744893**	**15082083**	**1488259**	**2385914**
City Construction Sources					
Pavements	53480	11704	15330	1400	4270
Housing	269310	20445	77198	7050	21503
Sub-Total (lbs)	**322790**	**32149**	**92528**	**8450**	**25773**
City Total (tons)	**10595**	**1889**	**7587**	**748**	**1206**

Table D.26: 1998 Emissions Summary in the Defined Spatial Boundaries

	CO (lbs)	VOC (lbs)	NOx (lbs)	SOx (lbs)	PM10(lbs)
AFB Operation Sources					
Vehicles	595438	66440	56678	0	47887
T-37 Trim	8707	1106	179	88	32
T-37 LTO	557919	55584	19541	7691	1582
T-37 T&G	1114531	25306	80890	26272	418
T-38/AT-38 Trim	28877	4046	625	328	6
T-38/AT-38 LTO	2594790	376398	49856	26850	459
T-38/AT-38 T&G	2777998	150165	180942	79672	1050
Emission Inventory	53614	162044	66252	25571	19135
Const Related Ops	274	105	1307	8	157
4-Stroke Engines	54245	4837	616	74	88
Residential NG Use	4288	1179	10076	64	1198
Sub-Total (lbs)	**7790681**	**847210**	**466962**	**166618**	**72012**
AFB Construction Sources					
Water System	2292	174	548	50	153
Facility Disposal	0	0	-2	0	0
Sewer System	53480	4060	15330	1400	4270
Storm Drain	0	0	0	0	0
NG System	0	0	0	0	0
Electrical System	0	0	0	0	0
New Construction	0	0	0	0	0
Pavements	2559	5738	734	67	204
Roofing	0	0	0	0	0
Key/MILCON	10581	803	3033	277	845
Sub-Total (lbs)	**68912**	**10775**	**19643**	**1794**	**5472**
AFB Total (tons)	**3930**	**429**	**243**	**84**	**39**
City Operations Sources					
Vehicles	15296135	1362156	1862029	0	1900520
Commuter Aircraft	15438	18976	2821	430	1017
Emission Summary	3000687	485947	12650020	1482456	418526
4-Stroke Engines	1749520	155991	19877	2382	2840
Comm/Consum VOC	0	1647966	0	0	0
Comm/Res NG Use	129201	43874	493560	3007	59101
Sub-Total (lbs)	**20190981**	**3714910**	**15028307**	**1488275**	**2382004**
City Construction Sources					
Pavements	87478	19176	25076	2290	6985
Housing	269310	20445	77198	7050	21503
Sub-Total (lbs)	**356788**	**39621**	**102274**	**9340**	**28488**
City Total (tons)	**10274**	**1877**	**7565**	**749**	**1205**

Table D.27: 1999 Emissions Summary in the Defined Spatial Boundaries

AFB Operation Sources	CO (lbs)	VOC (lbs)	NOx (lbs)	SOx (lbs)	PM10(lbs)
Vehicles	546001	62661	55104	0	47320
T-37 Trim	8707	1106	179	88	32
T-37 LTO	557919	55584	19541	7691	1582
T-37 T&G	1114531	25306	80890	26272	418
T-38/AT-38 Trim	28877	4046	625	328	6
T-38/AT-38 LTO	2594790	376398	49856	26850	459
T-38/AT-38 T&G	2777998	150165	180942	79672	1050
Emission Inventory	53614	162044	66252	25571	19135
Const Related Ops	376	144	1791	11	215
4-Stroke Engines	54245	4837	616	74	88
Residential NG Use	4288	1179	10076	64	1198
Sub-Total (lbs)	**7741346**	**843470**	**465872**	**166621**	**71503**
AFB Construction Sources					
Water System	16426	1247	4709	430	1312
Facility Disposal	-28	-11	-132	-1	-16
Sewer System	0	0	0	0	0
Storm Drain	1146	87	329	30	92
NG System	14134	1073	4052	370	1129
Electrical System	5730	435	1643	150	458
New Construction	0	0	0	0	0
Pavements	6265	9840	1796	164	500
Roofing	0	959	0	0	0
Key/MILCON	497	38	142	13	40
Sub-Total (lbs)	**44170**	**13668**	**12539**	**1156**	**3515**
AFB Total (tons)	**3893**	**429**	**239**	**84**	**38**
City Operations Sources					
Vehicles	14608716	1300517	1818198	0	1897492
Commuter Aircraft	15438	18976	2821	430	1017
Emission Summary	3000687	485947	12650020	1482456	418526
4-Stroke Engines	1755458	156521	19944	2390	2849
Comm/Consum VOC	0	1665048	0	0	0
Comm/Res NG Use	129652	43998	494621	3014	59227
Sub-Total (lbs)	**19509951**	**3671007**	**14985604**	**1488290**	**2379111**
City Construction Sources					
Pavements	15280	2533	4380	400	1220
Housing	269310	20445	77198	7050	21503
Sub-Total (lbs)	**284590**	**22978**	**81578**	**7450**	**22723**
City Total (tons)	**9897**	**1847**	**7534**	**748**	**1201**

Table D.28: 2000 Emissions Summary in the Defined Spatial Boundaries

	CO (lbs)	VOC (lbs)	NOx (lbs)	SOx (lbs)	PM10(lbs)
AFB Operation Sources					
Vehicles	496250	59197	53215	0	46804
T-37 Trim	8707	1106	179	88	32
T-37 LTO	557919	55584	19541	7691	1582
T-37 T&G	1114531	25306	80890	26272	418
T-38/AT-38 Trim	28877	4046	625	328	6
T-38/AT-38 LTO	2594790	376398	49856	26850	459
T-38/AT-38 T&G	2777998	150165	180942	79672	1050
Emission Inventory	53614	162044	66252	25582	19135
Const Related Ops	381	146	1815	11	218
4-Stroke Engines	54245	4837	616	74	88
Residential NG Use	4288	1179	10076	64	1198
Sub-Total (lbs)	**7691600**	**840008**	**464007**	**166632**	**70990**
AFB Construction Sources					
Water System	3438	261	986	90	275
Facility Disposal	-17	-7	-83	0	-10
Sewer System	53480	4060	15330	1400	4270
Storm Drain	0	0	0	0	0
NG System	4584	348	1314	120	366
Electrical System	2292	174	657	60	183
New Construction	0	0	0	0	0
Pavements	5730	7085	1643	150	500
Roofing	0	0	0	0	0
Key/MILCON	3285	249	942	86	262
Sub-Total (lbs)	**72792**	**12170**	**20789**	**1906**	**5846**
AFB Total (tons)	**3882**	**426**	**242**	**84**	**38**
City Operations Sources					
Vehicles	13903940	1237323	1773071	0	1896038
Commuter Aircraft	15438	18976	2821	430	1017
Emission Summary	3000687	485947	12650020	1482456	418526
4-Stroke Engines	1761397	157050	20012	2398	2859
Comm/Consum VOC	0	1682129	0	0	0
Comm/Res NG Use	130104	44122	495681	3020	59353
Sub-Total (lbs)	**18811566**	**3625547**	**14941605**	**1488304**	**2377793**
City Construction Sources					
Pavements	72198	15774	20696	1890	5765
Housing	269310	20445	77198	7050	21503
Sub-Total (lbs)	**341508**	**36219**	**97894**	**8940**	**27268**
City Total (tons)	**9577**	**1831**	**7520**	**749**	**1203**

Table D.29: 2001 Emissions Summary in the Defined Spatial Boundaries

AFB Operation Sources					
	CO (lbs)	VOC (lbs)	NOx (lbs)	SOx (lbs)	PM10(lbs)
Vehicles	489008	58883	52900	0	46338
T-37 Trim	8707	1106	179	88	32
T-37 LTO	557919	55584	19541	7691	1582
T-37 T&G	1114531	25306	80890	26272	418
T-38/AT-38 Trim	28877	4046	625	328	6
T-38/AT-38 LTO	2594790	376398	49856	26850	459
T-38/AT-38 T&G	2777998	150165	180942	79672	1050
Emission Inventory	53614	162044	66252	25571	19135
Const Related Ops	412	158	1961	12	236
4-Stroke Engines	54245	4837	616	74	88
Residential NG Use	4288	1179	10076	64	1198
Sub-Total (lbs)	**7684389**	**839706**	**463838**	**166622**	**70542**
AFB Construction Sources					
Water System	3438	261	986	90	275
Facility Disposal	-17	-7	-83	0	-10
Sewer System	53480	4060	15330	1400	4270
Storm Drain	0	0	0	0	0
NG System	4584	348	1314	120	366
Electrical System	3056	232	876	80	244
New Construction	0	0	0	0	0
Pavements	5730	7085	1643	150	500
Roofing	0	0	0	0	0
Key/MILCON	320269	24314	91805	8384	25571
Sub-Total (lbs)	**390540**	**36293**	**111871**	**10224**	**31216**
AFB Total (tons)	**4037**	**438**	**288**	**88**	**51**
City Operations Sources					
Vehicles	13942047	1249888	1791076	0	1896222
Commuter Aircraft	15438	18976	2821	430	1017
Emission Summary	3000687	485947	12650020	1482456	418526
4-Stroke Engines	1767335	157580	20079	2406	2868
Comm/Consum VOC	0	1699211	0	0	0
Comm/Res NG Use	130555	44246	496741	3027	59479
Sub-Total (lbs)	**18856062**	**3655848**	**14960737**	**1488319**	**2378112**
City Construction Sources					
Pavements	21086	5333	6044	552	1684
Housing	269310	20445	77198	7050	21503
Sub-Total (lbs)	**290396**	**25778**	**83242**	**7602**	**23187**
City Total (tons)	**9573**	**1841**	**7522**	**748**	**1201**

Table D.30: 2002 Emissions Summary in the Defined Spatial Boundaries

	CO (lbs)	VOC (lbs)	NOx (lbs)	SOx (lbs)	PM10(lbs)
AFB Operation Sources					
Vehicles	481766	58568	52900	0	45922
T-37 Trim	8707	1106	179	88	32
T-37 LTO	557919	55584	19541	7691	1582
T-37 T&G	1114531	25306	80890	26272	418
T-38/AT-38 Trim	28877	4046	625	328	6
T-38/AT-38 LTO	2594790	376398	49856	26850	459
T-38/AT-38 T&G	2777998	150165	180942	79672	1050
Emission Inventory	53614	162044	66252	25571	19135
Const Related Ops	9037	989	2874	29	373
4-Stroke Engines	54245	4837	616	74	88
Residential NG Use	4288	1179	10076	64	1198
Sub-Total (lbs)	**7685772**	**840222**	**464751**	**166639**	**70263**
AFB Construction Sources					
Water System	0	0	0	0	0
Facility Disposal	-2	-1	-8	0	-1
Sewer System	0	0	0	0	0
Storm Drain	0	0	0	0	0
NG System	0	0	0	0	0
Electrical System	0	0	0	0	0
New Construction	0	0	0	0	0
Pavements	0	0	0	0	0
Roofing	0	0	0	0	0
Key/MILCON	10314	783	2957	270	824
Sub-Total (lbs)	**10312**	**782**	**2949**	**270**	**823**
AFB Total (tons)	**3848**	**421**	**234**	**83**	**36**
City Operations Sources					
Vehicles	13978082	1249438	1796066	0	1898104
Commuter Aircraft	15438	18976	2821	430	1017
Emission Summary	3000687	485947	12650020	1482456	418526
4-Stroke Engines	1773273	158109	20147	2414	2878
Comm/Consum VOC	0	1716293	0	0	0
Comm/Res NG Use	131006	44370	497802	3034	59606
Sub-Total (lbs)	**18898486**	**3673133**	**14966856**	**1488334**	**2380131**
City Construction Sources					
Pavements	58446	12819	16754	1530	4667
Housing	269310	20445	77198	7050	21503
Sub-Total (lbs)	**327756**	**33264**	**93952**	**8580**	**26170**
City Total (tons)	**9613**	**1853**	**7530**	**748**	**1203**

Table D.31: 2003 Emissions Summary in the Defined Spatial Boundaries

	CO (lbs)	VOC (lbs)	NOx (lbs)	SOx (lbs)	PM10(lbs)
AFB Operation Sources					
Vehicles	474209	58253	52585	0	45557
T-37 Trim	8707	1106	179	88	32
T-37 LTO	557919	55584	19541	7691	1582
T-37 T&G	1114531	25306	80890	26272	418
T-38/AT-38 Trim	28877	4046	625	328	6
T-38/AT-38 LTO	2594790	376398	49856	26850	459
T-38/AT-38 T&G	2777998	150165	180942	79672	1050
Emission Inventory	53614	162044	66252	25571	19135
Const Related Ops	9135	1026	3339	32	429
4-Stroke Engines	54245	4837	616	74	88
Residential NG Use	4288	1179	10076	64	1198
Sub-Total (lbs)	**7678313**	**839944**	**464901**	**166642**	**69954**
AFB Construction Sources					
Water System	0	0	0	0	0
Facility Disposal	-90	-34	-430	-3	-52
Sewer System	0	0	0	0	0
Storm Drain	0	0	0	0	0
NG System	0	0	0	0	0
Electrical System	0	0	0	0	0
New Construction	0	0	0	0	0
Pavements	0	0	0	0	0
Roofing	0	0	0	0	0
Key/MILCON	29032	2204	8322	760	2318
Sub-Total (lbs)	**28942**	**2170**	**7892**	**757**	**2266**
AFB Total (tons)	**3854**	**421**	**236**	**84**	**36**
City Operations Sources					
Vehicles	14025189	1261873	1813942	0	1901747
Commuter Aircraft	15438	18976	2821	430	1017
Emission Summary	3000687	485947	12650020	1482456	418526
4-Stroke Engines	1779211	158639	20214	2422	2888
Comm/Consum VOC	0	1733374	0	0	0
Comm/Res NG Use	131457	44494	498862	3041	59732
Sub-Total (lbs)	**18951982**	**3703303**	**14985859**	**1488349**	**2383910**
City Construction Sources					
Pavements	28650	6268	8213	750	2288
Housing	269310	20445	77198	7050	21503
Sub-Total (lbs)	**297960**	**26713**	**85411**	**7800**	**23791**
City Total (tons)	**9625**	**1865**	**7536**	**748**	**1204**

Table D.32: 2004 Emissions Summary in the Defined Spatial Boundaries

AFB Operation Sources	CO (lbs)	VOC (lbs)	NOx (lbs)	SOx (lbs)	PM10(lbs)
Vehicles	466967	57938	52585	0	45229
T-37 Trim	8707	1106	179	88	32
T-37 LTO	557919	55584	19541	7691	1582
T-37 T&G	1114531	25306	80890	26272	418
T-38/AT-38 Trim	28877	4046	625	328	6
T-38/AT-38 LTO	2594790	376398	49856	26850	459
T-38/AT-38 T&G	2777998	150165	180942	79672	1050
Emission Inventory	53614	162044	66252	25571	19135
Const Related Ops	9412	1132	4659	40	587
4-Stroke Engines	54245	4837	616	74	88
Residential NG Use	4288	1179	10076	64	1198
Sub-Total (lbs)	**7671348**	**839735**	**466221**	**166650**	**69784**
AFB Construction Sources					
Water System	0	0	0	0	0
Facility Disposal	0	0	0	0	0
Sewer System	0	0	0	0	0
Storm Drain	0	0	0	0	0
NG System	0	0	0	0	0
Electrical System	0	0	0	0	0
New Construction	0	0	0	0	0
Pavements	0	0	0	0	0
Roofing	0	0	0	0	0
Key/MILCON	1910	145	548	50	153
Sub-Total (lbs)	**1910**	**145**	**548**	**50**	**153**
AFB Total (tons)	**3837**	**420**	**233**	**83**	**35**
City Operations Sources					
Vehicles	14057209	1261034	1818544	0	1906683
Commuter Aircraft	15438	18976	2821	430	1017
Emission Summary	3000687	485947	12650020	1482456	418526
4-Stroke Engines	1785150	159168	20282	2430	2897
Comm/Consum VOC	0	1750456	0	0	0
Comm/Res NG Use	131908	44619	499922	3047	59858
Sub-Total (lbs)	**18990392**	**3720200**	**14991589**	**1488363**	**2388981**
City Construction Sources					
Pavements	56154	12238	19097	1470	4484
Housing	269310	20445	77198	7050	21503
Sub-Total (lbs)	**325464**	**32683**	**96295**	**8520**	**25987**
City Total (tons)	**9658**	**1876**	**7544**	**748**	**1207**

Table D.33: 2005 Emissions Summary in the Defined Spatial Boundaries

	CO (lbs)	VOC (lbs)	NOx (lbs)	SOx (lbs)	PM10(lbs)
AFB Operation Sources					
Vehicles	459724	57623	52270	0	44952
T-37 Trim	8707	1106	179	88	32
T-37 LTO	557919	55584	19541	7691	1582
T-37 T&G	1114531	25306	80890	26272	418
T-38/AT-38 Trim	28877	4046	625	328	6
T-38/AT-38 LTO	2594790	376398	49856	26850	459
T-38/AT-38 T&G	2777998	150165	180942	79672	1050
Emission Inventory	53614	162044	66252	25571	19135
Const Related Ops	9430	1139	4745	41	597
4-Stroke Engines	54245	4837	616	74	88
Residential NG Use	4288	1179	10076	64	1198
Sub-Total (lbs)	**7664123**	**839427**	**465992**	**166651**	**69517**
AFB Construction Sources					
Water System	0	0	0	0	0
Facility Disposal	0	0	0	0	0
Sewer System	0	0	0	0	0
Storm Drain	0	0	0	0	0
NG System	0	0	0	0	0
Electrical System	0	0	0	0	0
New Construction	0	0	0	0	0
Pavements	0	0	0	0	0
Roofing	0	0	0	0	0
Key/MILCON	0	0	0	0	0
Sub-Total (lbs)	**0**	**0**	**0**	**0**	**0**
AFB Total (tons)	**3832**	**420**	**233**	**83**	**35**
City Operations Sources					
Vehicles	14087155	1273339	1836290	0	1913494
Commuter Aircraft	15438	18976	2821	430	1017
Emission Summary	3000687	485947	12650020	1482456	418526
4-Stroke Engines	1791088	159698	20349	2438	2907
Comm/Consum VOC	0	1767537	0	0	0
Comm/Res NG Use	132360	44743	500983	3054	59984
Sub-Total (lbs)	**19026728**	**3750240**	**15010463**	**1488378**	**2395928**
City Construction Sources					
Pavements	25212	1914	7227	660	2013
Housing	269310	20445	77198	7050	21503
Sub-Total (lbs)	**294522**	**22359**	**84425**	**7710**	**23516**
City Total (tons)	**9661**	**1886**	**7547**	**748**	**1210**

emissions with and without the proposals and comparison of the total area emission levels with and without the proposed base activities. Figures D.3 through D.12 graphically present these comparisons individually for the criteria pollutants: CO, VOC, NO_x, SO_x, and PM_{10}.

Separate graphs were generated to display the emission change within the base boundaries and to display the effect of the base activities on the total city area. Note that no comparisons were made to determine the influence of the city proposals. The focus of a NEPA analysis is on federal activity effects, not private, local, or state activity effects. The information is presented in this format to emphasize the analysis focus. If desired, the analysis focus can be easily shifted to present the effects on the area from alternate viewpoints such as city or state government influence.

Careful inspection of these graphs shows that the largest effects occur in 1997 and 2001. However, it is important to interpret the graphs in context with the availability of information for any given year. In the later years of the study period, the emission effects of the proposed activities appears to taper off. By 2005, the emissions appear to return to almost the same level as was predicted in the absence of the base projects influence. Three points can be made with regard to this observation. First, it appears that, while base development activities will exert a short term influence on local and city-wide emissions, the long term, operational phase influence of those activities is minimal. Second, since the majority of the air pollution influence identified in this example seems to be caused by the construction activity, not the operation of the proposed facility, it may be appropriate to focus mitigation efforts on the construction processes. This does not mean that the construction phase will be of primary importance for mitigation consideration in every example. The value is in the ability of the assessment tool to identify the appropriate focus.

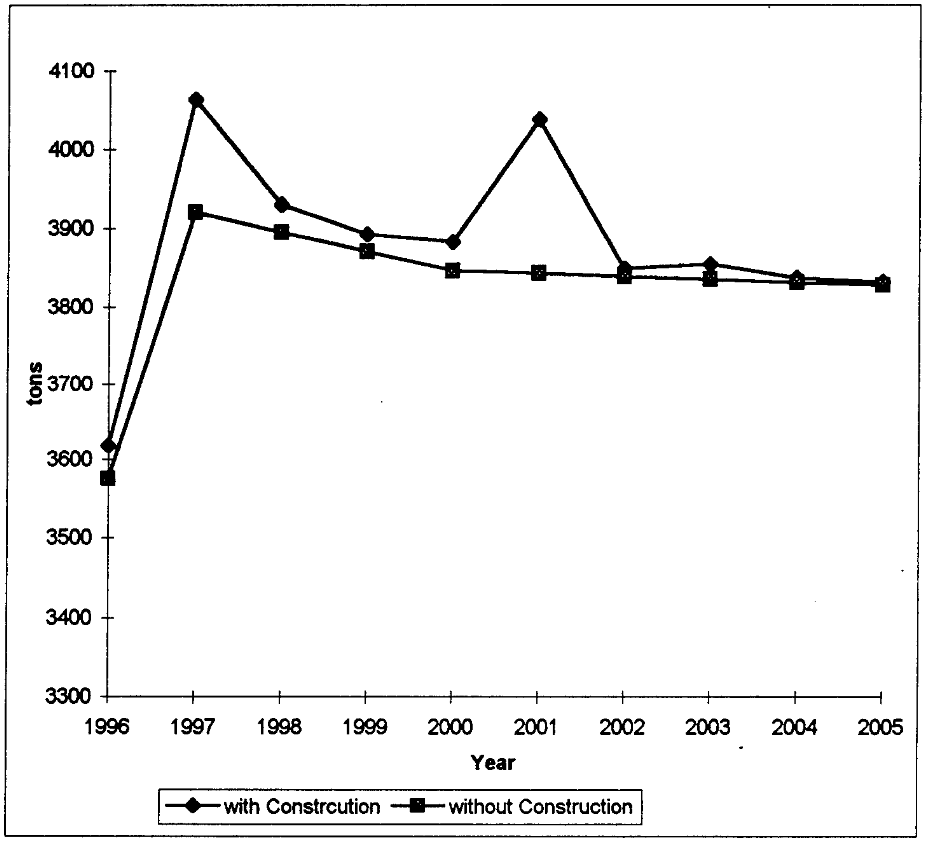


Figure D.3: AFB CO Comparisons

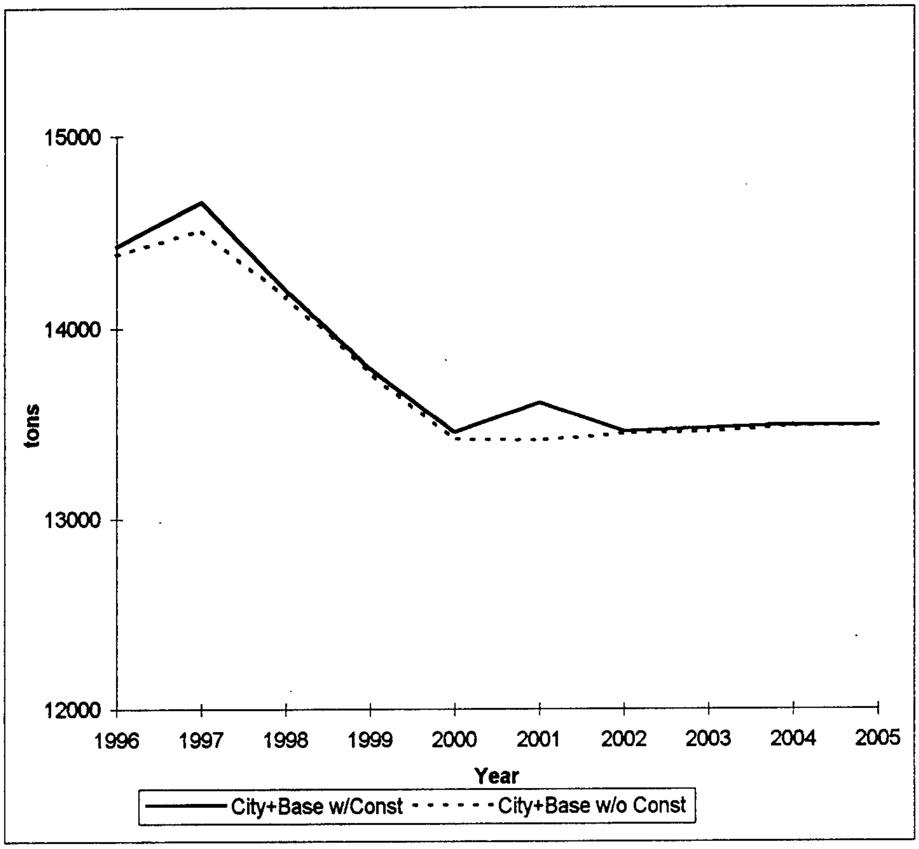


Figure D.4: AFB Project Effect on CO Emissions in the Study Area

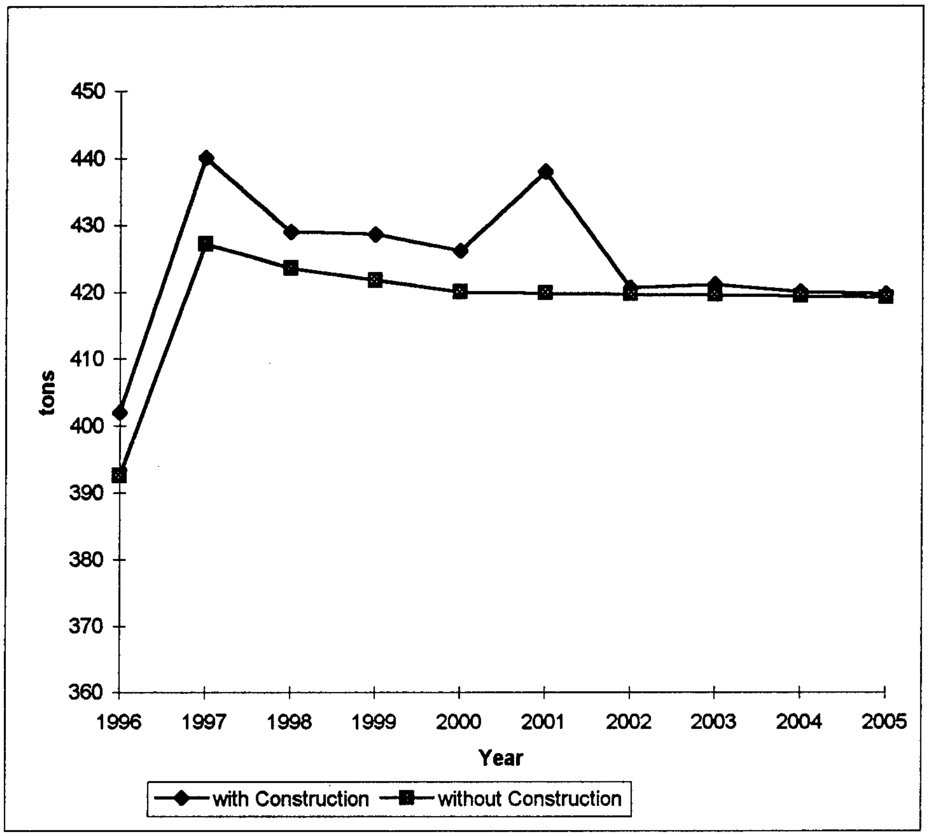


Figure D.5: AFB VOC Emission Comparisons

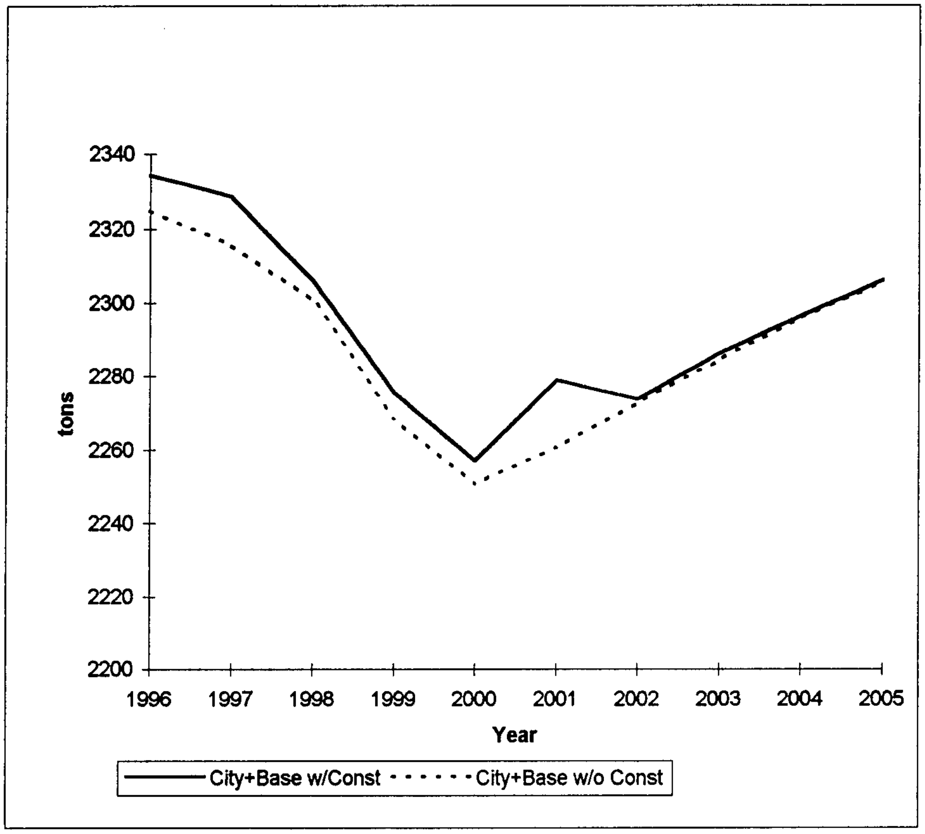


Figure D.6: AFB Project Effect on VOC Emissions in the Study Area

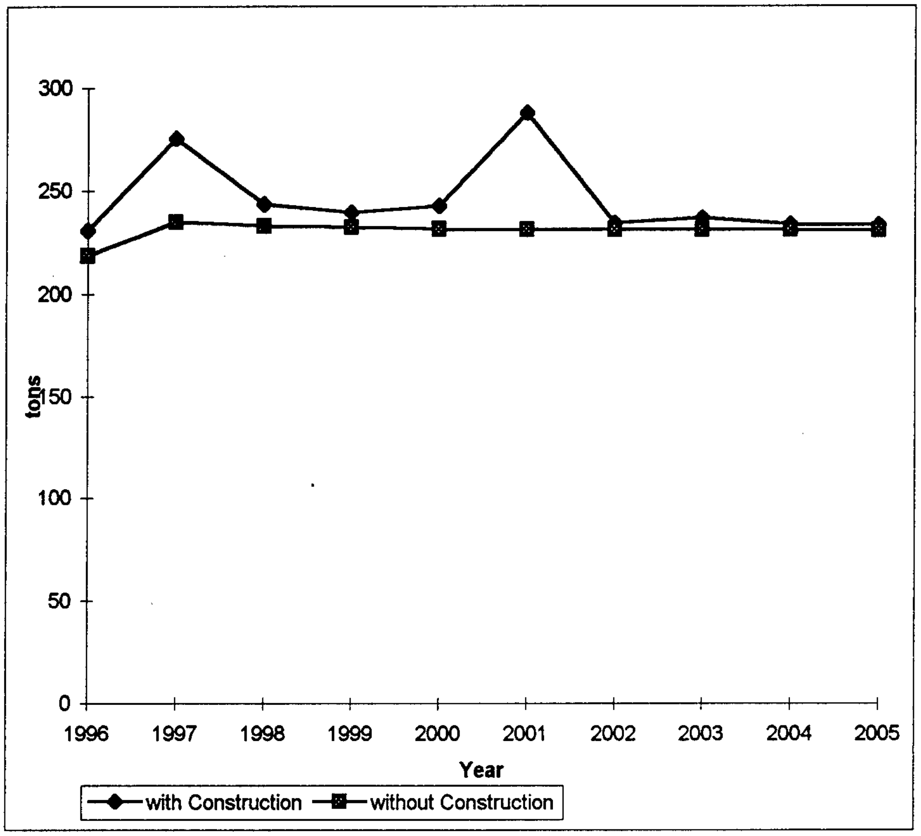


Figure D.7: AFB NOx Emission Comparisons

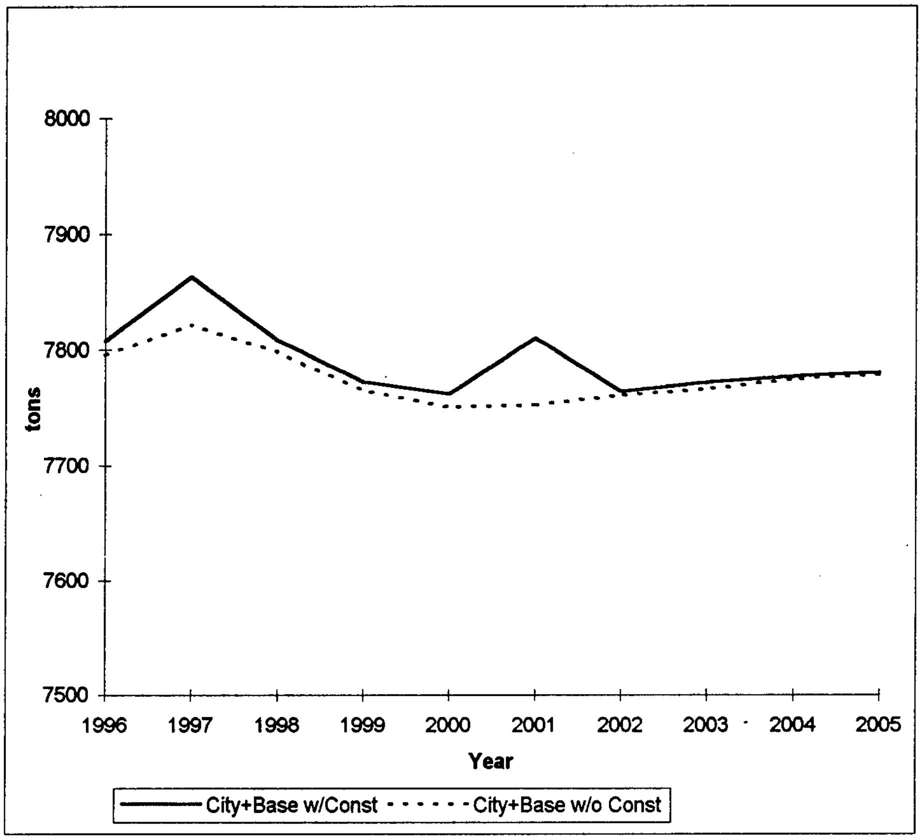


Figure D.8: AFB Project Effect on NOx Emissions in the Study Area

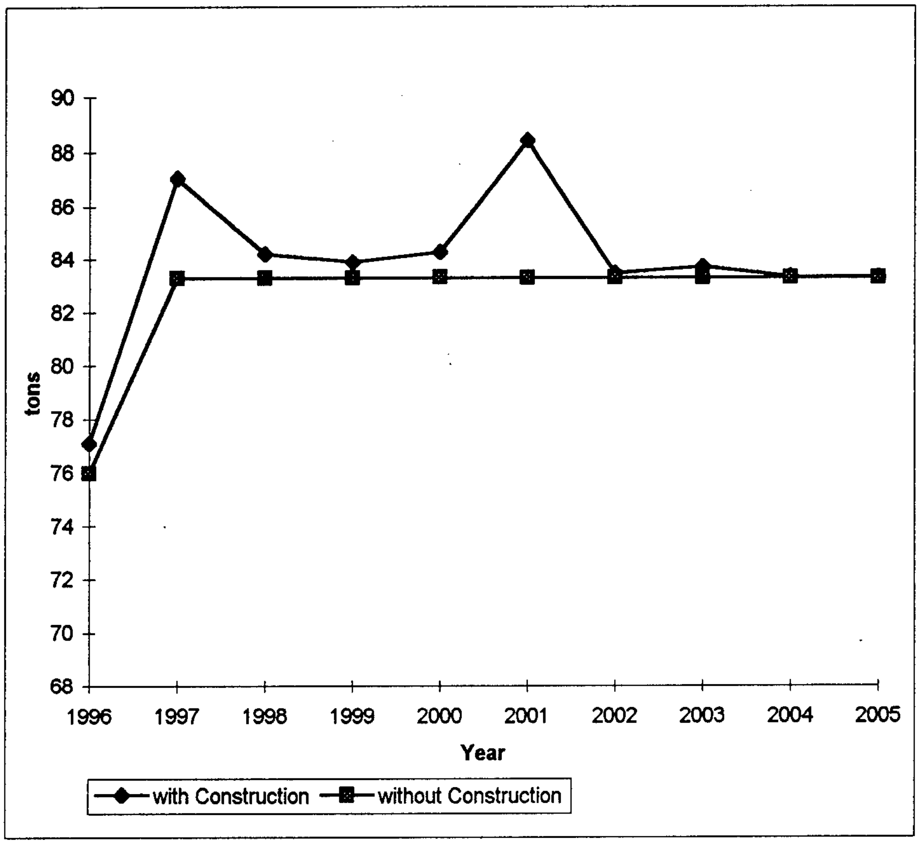


Figure D.9: AFB SOx Emission Comparisons

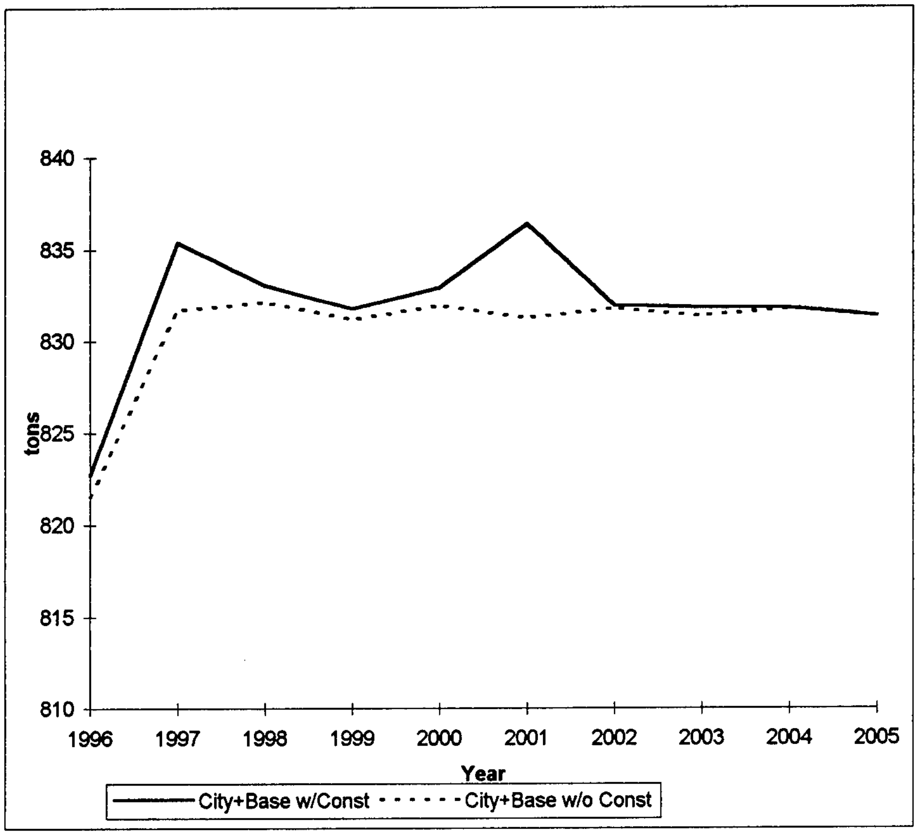


Figure D.10: AFB Project Effect on SOx Emissions in the Study Area

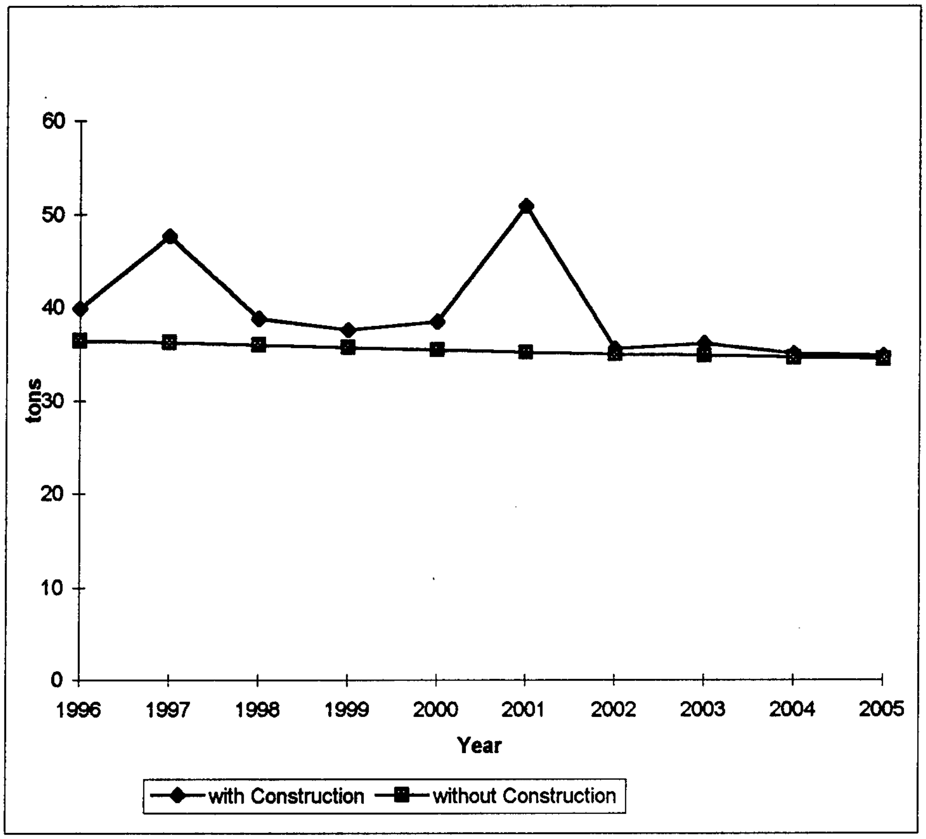


Figure D.11: AFB PM10 Emissions Comparisons

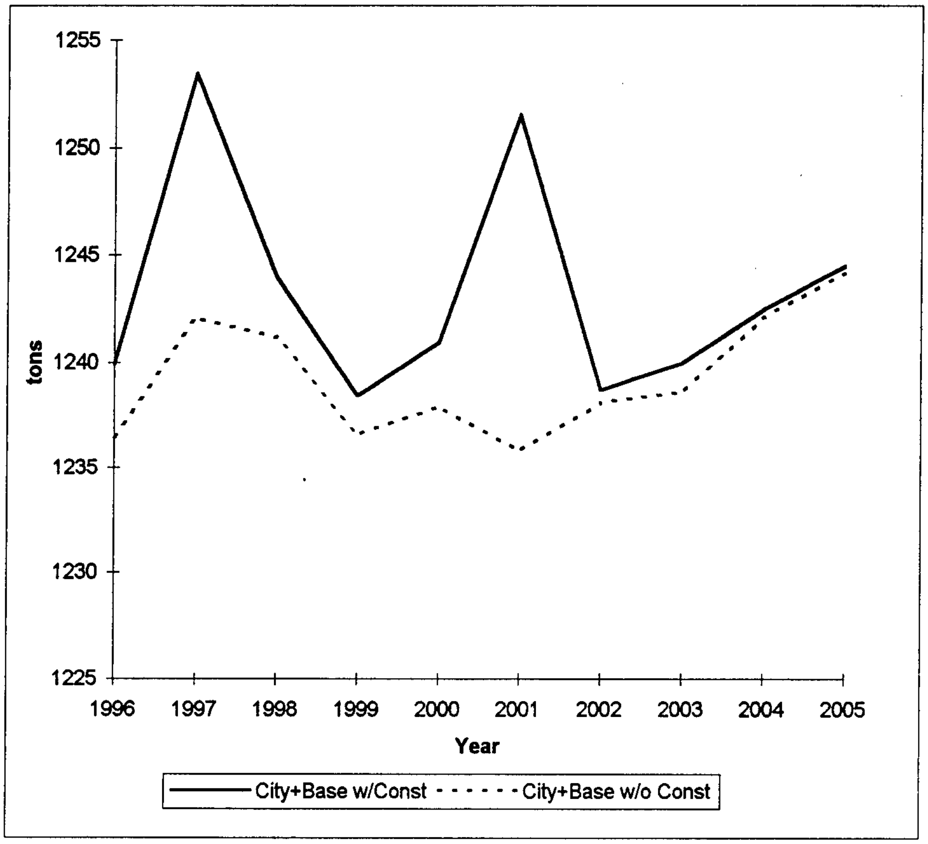


Figure D.12: AFB Project Effect on PM10 Emissions in the Study Area

And third, it is unlikely that base development activities will simply end by the year 2005. A more reasonable explanation is that development proposals for the later years of this study and beyond have not yet, even informally, been formulated. Were this study to be re-evaluated at a later time, it is likely that additional RFFAs would be available for inclusion that would elevate the development activity construction emissions for the time period of 2002 through 2005 to those similar to the first four to five years of the study period.

The graphical analysis presents the cumulative effect of base development activity over time for individual pollutants. While this is valuable, the analysis is still incomplete. A tabular presentation of the percentage increase in emission level, relative to each pollutant and year, can provide insight into effect significance and proper mitigation focus. Table D.34 presents the percent increase in the emission level of each pollutant, annually, throughout the study timeframe within the base boundaries. Table D.35 presents the same data for the base proposal influence with respect to the total city area emissions.

The graphical analysis revealed that 2001 was one of the years with the most extreme effect. The tabular presentation of the change in base emissions shows that, within the year 2001, base CO emissions increase 5.09%, VOC emissions increase 4.34%, NO_x emissions increase 24.65%, SO_x emissions increase 6.14%, and PM_{10} emissions increase 44.74%. This indicates that the primary areas of concern for the base, with regard to its local air quality, would be to focus its mitigation efforts on NO_x and PM_{10} emissions. However, when addressing the base proposal influence on total city area emissions, the focus of concern shifts. In the city context, the 2001 base proposal emissions result in a 2.04% increase in CO, a 0.99% increase in VOC, a 0.76% increase in NO_x, a 0.68% increase in SO_x, and a 1.31% increase in PM_{10} emissions. From the city viewpoint, the

Table D.34: Proposal Effect on AFB Emissions

Year	Pollutants (%)*				
	CO	VOC	NOx	SOx	PM10
1996	1.20	2.40	5.63	1.48	9.39
1997	3.64	3.02	17.46	4.49	31.47
1998	0.89	1.28	4.50	1.08	7.83
1999	0.58	1.64	3.09	0.70	5.23
2000	0.95	1.47	4.89	1.15	8.57
2001	5.09	4.34	24.65	6.14	44.74
2002	0.25	0.21	1.26	0.18	1.71
2003	0.50	0.38	2.43	0.47	3.88
2004	0.15	0.15	1.13	0.05	1.07
2005	0.12	0.14	1.03	0.02	0.87

*All percentages are increases in the emission levels over the 1996 emission levels (the base year chosen for this analysis without considering construction projects on the AFB)

Table D.35: AFB Proposal Effects on Total Study Area Emissions

Year	Pollutants (%)*				
	CO	VOC	NOx	SOx	PM10
1996	0.40	0.49	0.16	0.15	0.29
1997	1.35	0.68	0.54	0.50	0.95
1998	0.34	0.29	0.14	0.12	0.23
1999	0.23	0.37	0.10	0.08	0.16
2000	0.38	0.34	0.15	0.13	0.25
2001	2.04	0.99	0.76	0.68	1.31
2002	0.10	0.05	0.04	0.02	0.05
2003	0.20	0.09	0.07	0.05	0.11
2004	0.06	0.03	0.03	0.01	0.03
2005	0.05	0.03	0.03	0.00	0.02

*All percentages are increases in the emission levels over the 1996 emission levels (the base year chosen for this analysis without considering construction projects on the AFB)

primary pollutant of concern in CO. This demonstrates the importance of evaluating an activity's effect, not just on its immediate surroundings, but also with respect to the total area setting.

Additionally, the evaluation of cumulative emissions provides insight into the future of more complex atmospheric issues such as acid deposition and photochemical oxidant formation. Several studies have indicated that sulfur oxides and nitrogen oxides are the principal precursors to acid deposition (Canter, 1997). Evaluation of the change in emission levels of these two pollutants within the study area, therefore, provides information as to the future potential for acid precipitation.

A qualitative relationship between the major chemical and atmospheric variables active in photochemical oxidant formation, which includes urban ozone, can be expressed as (Cooper and Alley, 1994):

$$\text{PPL} = \frac{(\text{ROG})(\text{NO}_x)(\text{Light Intensity})(\text{Temperature})}{(\text{Wind Velocity})(\text{Inversion Height})}$$

where,

PPL = photochemical pollution level
ROG = concentration of reactive organic gases (to include VOCs)
NO_x = concentration of oxides of nitrogen.

It is readily apparent from this qualitative model that increases in NO_x and VOC emissions have strong potential to increase photochemical smog levels. Evaluation of the VOC/NO_x ratio assists in focusing mitigation efforts. When this ratio results in a value less than ten (VOC/NO_x < 10), the condition is called VOC limiting. When the ratio is greater than twenty (VOC/NO_x > 20), the condition is called NO_x limiting. The optimal mitigation strategy for prevention or reduction of photochemical smog formation is to focus emission control efforts on the pollutant termed as the limiting factor (Wolfe, 1993).

For the study case, the ratio indicates that the area condition is VOC limiting for all years addressed at both base and city area scales. However, as shown earlier, it is important to evaluate the ratio for both scale conditions to identify differences in the immediate surroundings and the total area conditions. Given the data obtained from the emission level analysis, combined with the background conditions and information regarding the adverse effects to humans, structures, and natural surroundings, these additional factors can, at least in a qualitative sense, provide input into significance intensity determinations.

Ambient Concentrations

While an evaluation of the change in emission levels provides a fairly complete assessment, it does not provide the assessor with an estimate of when, or if, ambient air quality standards (AAQS) will be exceeded. In order to determine the change to the ambient concentration resulting from the proposed federal activities, it is necessary to have observations or estimations on the existing ambient concentrations. Ambient air quality monitoring station data was collected for the area as part of the information search in Step 4. The only pollutant for which ambient data was available was PM_{10}. Since only one PM_{10} monitoring station was located within the study area, the average annual concentrations reported for this location were used as the average ambient concentration for the entire study area. It is not surprising, or uncommon, to find that ambient air quality monitoring data is not available for an area requiring NEPA analysis.

Cumulative air quality effects can be quantified and analyzed with the assistance of simple modeling techniques. Those suggested include rollback, simple area source, and box models. The available data was compared to the input requirements of each model type.

The box model appeared to be appropriate to the data collected for this application. No implication is intended as to the suitability of the other models to cumulative assessments. Other assessments may find one of the others to be suitable.

Multiple equations are available for box modeling. Gifford and Hanna demonstrated the utility of box model application to long term urban air quality analysis using the equation (Benarie, 1980):

$$X = \mathrm{c}\,\frac{Q}{A\bar{u}}$$

where,

X = the ambient concentration
Q = the total area emissions
A = the area
$\bar{u}$ = the annual average wind speed, and
c = a correction factor applied in a model calibration exercise

The reason that the correction factor is needed is to account for a model physics error inherent to the box model. Box models assume that the pollutant emissions are uniformly mixed in the entire volume of air. While some mixing will occur, factors such as the location of emission sources (ground level) cause the actual pollutant distribution to be non-uniform with the highest concentrations near the emission sources. The desired comparison in ambient air quality modeling is to relate the predicted concentrations to the observed values from monitoring stations. Monitoring stations are located so that the average pollutant concentration respirated by the human population can be determined. In other words, the monitoring stations are located near the ground level emission sources. Table D.36 provides the placement heights required by the USEPA for CO, O_3, NO_2, SO_2, and

Table D.36: Ambient Air Quality Monitoring Station Probe Siting Criteria (after 40 CFR 58 App. E)

Pollutant	Scale	Height Above Ground (meters)
SO_2	All	3 - 15
CO	Micro	3 ± 0.5
	Middle and Neighborhood	3 - 15
O_3	All	3 - 15
NO_2	All	3 - 15
PM_{10}	Micro	2 - 7
	Middle, Neighborhood, Urban, and Regional	2 - 15

PM_{10} monitoring stations intended as part of state and local or national ambient air quality monitoring networks.

Gifford and Hanna demonstrated their application of the box model in 29 major urban areas for both SO_2 and particulate matter to determine annual average concentrations Benarie, 1980). Using ambient air quality monitoring data for calibration, they found that an average correction factor of 50 should be applied for SO_2 and 202 for particulates. The reason given for the difference in correction factor between the two pollutants was that the sulfur dioxide emissions accounted for in the respective inventories included a large fraction associated with tall stacks (Benarie, 1980). Emissions from these tall stacks would disperse differently than emissions from ground level sources and therefore, this would reflect on the concentrations observed at the monitoring stations. The correction factors obtained for each city varied for particulates from a low of 57 to over 600. Similar variation was found in correction factors for sulfur dioxide. These box model applications were all applied to large urban centers. Finally, in a related study, Wu found that, for small urban areas, an average correction factor of 892 was more appropriate (Benarie, 1980).

This current study was performed on an urban area (population in the range of 100,000) that can easily be categorized as small. Table D.37 presents the 1996 annual average concentrations calculated for PM_{10} with the influence of the proposed base activities using the same form of the box model as Gifford and Hanna. Table D.38 demonstrates an additional box model application to the same data that more easily displays the effect of the uniform mixing assumption by directly applying the average annual mixing height. The results are not identical, however, they are of similar magnitude and when compared to the ambient monitoring station data, both are much lower than the observed annual average

Table D.37: Uncalibrated Gifford and Hanna Box Model Calculations

<u>Available Information</u>

1996 Total PM_{10} Emissions = 2,479,807 lbs/yr (from Table D.24)
Local Annual Average Wind Speed = 5.66 m/s (from local weather data)
City Plus AFB Area Dimension - x (windward) = 18,288 m
- y (crosswind) = 14,630 m

Using the uncorrected equation:

$$X = \frac{Q}{A\bar{u}}$$

2,479,807 lbs/yr = 35,661,752 μg/s

X = (35,661,752)/(18,288 x 14,630 x 5.66) = 0.02355 $\mu g/m^3$

Using the uncorrected equation:

$$X = c\frac{Q}{A\bar{u}}$$

c = 202 (based on study of 29 urban areas, many of which were larger than the urban area in this example

X = (202)(0.02355) = 4.56 $\mu g/m^3$

Table D.38: Alternate Uncalibrated Box Model Calculation Demonstrating Mixing Height Influence

Available Information

1996 Total PM_{10} Emissions = 2,479,807 lbs/yr
Local Annual Average Morning Mixing Height (from Holzworth, 1972) = 400 m
Local Annual Average Afternoon Mixing Height (from Holzworth, 1972) = 1400 m
City Plus Base Area Dimension - x (windward) = 18,288 m
- y (crosswind) = 14,630 m
Typical time for which uniform mixing assumption is valid, t = 1 hr or 3600 sec.

Using the equation:

$$C = \frac{Qt}{xyz}$$

2,479,807 lbs/yr = 35,661,752 μg/s

For Morning Conditions:

C = (35,661,752)(3600)/(18,288 x 14,630 x 400) = 1.2 μg/m^3

For Afternoon Conditions:

C = (35,661,752)(3600)/(18,288 x 14,630 x 1400) = 0.34 μg/m^3

concentration of 19 μg/m^3. Returning to the Gifford and Hanna model for comparative purposes, Table D.39 presents the calculations for the determination of an appropriate correction factor for this study and its application to future emission projections. The correction factor determined here (807) compares well to the average for small urban sources (892) developed by Wu (Benarie, 1980) assuming that the proportion of PM_{10} in particulate matter remains relatively constant over the analysis. The largest annual PM_{10} increase over the 10 year period is 0.24 μg/m^3.

The analysis of air quality effects resulting from federal activities is often required in areas where ambient air quality monitoring data is not available. In such cases, the average correction factors for the appropriate urban center size, determined by Gifford and Hanna, and later Wu, could be applied. These values are, however, averages. Application of an average value to a specific situation introduces the additional error of the degree of difference between the application site and average conditions. This approach can provide the assessor with a sense of relative change on ambient air quality resulting from the proposed activities, however; the predicted values should not be accepted as representative of the actual future concentrations. The average correction factors should only be used to determine the trend (e.g. increasing, decreasing, stable) in the ambient concentration resulting from the proposed activities.

This modeling procedure can also be applied to the evaluation of long-range transport effects. Downwind transport determinations should be made where there is some considerable effect on ambient air quality, or where concern is expressed over pollutant transport to the new location. To evaluate this effect, modify the area to include the downwind receptor location and recalculate the ambient concentrations using only the source

Table D.39: Calibrated Box Model Results for PM_{10}

Using the equation:

$$X = c\frac{Q}{A\bar{u}}$$

Set X = 19 μg/m³

Solving the equation for c with the 1996 data
(0.02355 μg/m³ from Table D.37):

$$c = 806.8 \cong 807$$

Applying this equation with the correction factor to the projected PM_{10} emissions throughout the study period yields the following results:

Year	Projected Ambient Concentration With Proposed AFB Activities (μg/m³)	Projected Ambient Concentration Without Proposed AFB Activities (μg/m³)	Increase (μg/m³)
1996	19.00	18.95	0.05
1997	19.21	19.04	0.17
1998	19.07	19.02	0.05
1999	18.98	18.95	0.03
2000	19.02	18.97	0.05
2001	19.18	18.94	0.24
2002	18.99	18.98	0.01
2003	19.01	18.98	0.03
2004	19.04	19.04	0.00
2005	19.07	19.07	0.00

emission contributions from the original area as shown in Figure D.13. This will not provide the assessor with a prediction of the actual ambient concentration at the downwind area. It will; however, provide the study area's contribution to the overall air quality in the downwind area. With ambient data obtained relative to this new receptor, the percentage contribution resulting from the study area activities can be determined.

STEP 7 -- SIGNIFICANCE DETERMINATION

The significance of these predicted air quality effects can be interpreted with the multi-criteria decision making method presented in Chapter 5. Recommendations for rating factor intensities are shown in Table D.40. Based on these recommendations, Table D.41 presents the intensity ratings for the data collected and developed in this example relative to AFB level PM_{10} emissions. Similar intensity ratings were developed for the total study area PM_{10} emissions and for each of the other pollutants relative to each boundary condition. Tables D.42 through D.51 present the factor weights and matrix calculations to determine the "weighted effect" significance score for each pollutant and boundary condition. Table D.52 presents a comparison of these scores to demonstrate the change in significance based on spatial perspective.

Based on this assessment, the cumulative air quality effects are not significant. However, it should be noted that NO_x and PM_{10} emission levels are significantly increased in the local area of the Air Force base. Standard practices for limiting air pollutant emissions were identified in the emission calculation portion of the assessment. Calculations were based on the assumption that these measures would be employed. However, the significance determinations were made with the assumption that no further mitigation efforts would be

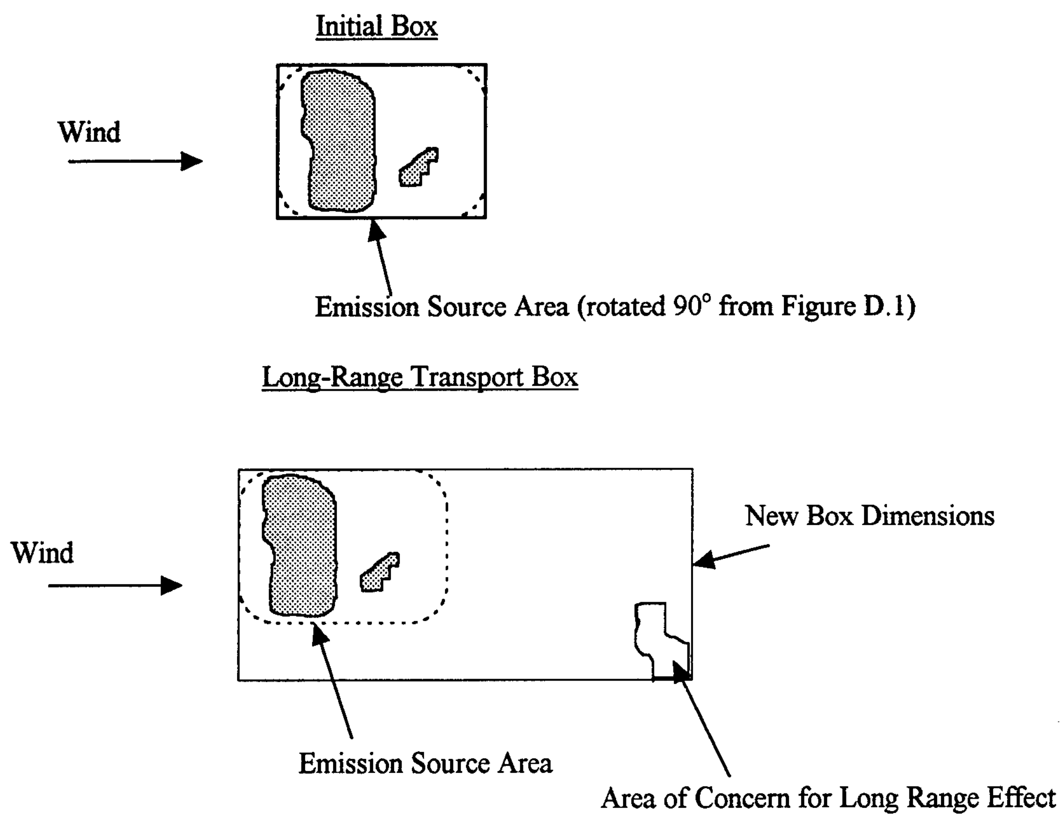


Figure D.13: Long Range Pollutant Transport Analysis

Table D.40: Factor Intensity Ratings for Cumulative Air Quality Effects

Factor	Cumulative Intensity High (3)	Moderate (2)	Low (1)
<u>Pollutant Emissions</u>			
- % change in emission level	10% or greater increase	5 - 9% increase	< 5% increase
- timing, duration, and rate of change	occurs early in study period, > 5 years duration, high rate of increase	occurs midway through study period, 1 - 5 years duration, moderate rate of increase	occurs late in study period, < 1 year duration, slow rate of increase
- comparison to emission limitations (% noncompliance)	10% or greater	5 - 9%	< 5%
<u>Ambient Air Quality Standards</u>			
- change in ambient concentration	> 5% increase	1 - 5% increase	< 1% increase
- timing, duration, and rate of change	occurs early in study period, > 5 years duration, high rate of increase	occurs midway through study period, 1 - 5 years duration, moderate rate of increase	occurs late in study period, < 1 year duration, slow rate of increase
- violation of standards	cause new violation	impairs plans to mitigate existing violation	small contribution to existing violation
- influence on air pollution episodes	new occurrence where none observed before or large increase in existing number of episodes	moderate increase in existing episode frequency or required level of response	small increase in existing episode frequency or required level of response
- influence on current area classification	exceeds classification based limits	classification based limits reached	limits future development
<u>Public Perception</u>			
- level of public concern	high level of concern expressed	some concern expressed	little concern expressed
<u>Secondary/Indirect/Synergistic Effects</u>			
- influence on PPL potential	10% or greater increase in precursor emissions	5 - 9% increase in precursor emissions	< 5% increase in precursor emissions
- influence on VOC/NO_x ratio	10% or greater increase to limiting pollutant or change of limiting pollutant	5 - 9% increase to limiting pollutant	< 5% increase to limiting pollutant
- influence on stratospheric ozone	large increase in ODC emissions	moderate increase in ODC emissions	small increase in ODC emissions
- influence on global warming	large increase in precursor emissions	moderate increase in precursor emissions	small increase in precursor emissions
- spatial (transboundary) transport	large contribution to downwind area concentration	moderate contribution to downwind area concentration	small contribution to downwind area concentration
- influence on acid deposition potential	large increase in precursor emissions	moderate increase in precursor emissions	small increase in precursor emissions
<u>Human Health</u>			
- level of carcinogenic effect	known human carcinogen	probable human carcinogen	possible human carcinogen
- level of non-carcinogenic effect (dose response relationships, comparison to thresholds, synergisms, etc.)	<u>Air Toxics</u> - concentration above MAAC (or TLV/1000) <u>Others</u> - high likelihood of adverse effect	<u>Air Toxics</u> - concentration at MAAC (or TLV/1000) <u>Others</u> - moderate likelihood of adverse effect	<u>Air Toxics</u> - measurable conc. below MAAC (or TLV/1000) <u>Others</u> - low but identifiable possibility of adverse effect
<u>Mitigation</u>			
- timing/focus of mitigation vs. timing/focus of effects	allows for long-term (>5 years) continuance of mitigable effect	allows for continuance of mitigable effect for 1 - 5 years	allows for continuance of mitigable effect for less than one year

ODC = Ozone Depleting Chemical, MAAC = Maximum Allowable Ambient Concentration, TLV = Threshold Limit Value

Note: Shift in pollutant of concern factor intensity ratings not included (addressed through separate ratings for each spatial boundary condition)

Table D.41: Factor Intensity Ratings for AFB Level PM_{10}

Factor	Analysis Data	Cumulative Intensity Rating
Pollutant Emissions - % change in emission level	at least 1 year has >10% increase (44.74% highest noted in Table D.34)	3
- timing, duration, and rate of change	Figure D.11 shows 2 peaks of moderate increase, one early and one midway through the study, each lasts for 1 year	2
- comparison to emission limitations (% noncompliance)	all compliance limits met	0
Ambient Air Quality Standards - change in ambient concentration	<1% increase across study timeframe (0.24 $\mu g/m^3$ highest noted in Table D.39)	1
- timing, duration, and rate of change	extremely slow increases observed in initial half of study period (see Table D.39)	1
- violation of standards	no violations	0
- influence on air pollution episodes	no episodes expected	0
- influence on current area classification	no predicted limitations on development or change in classification	0
Public Perception - level of public concern	subject occasionally broached in meetings, small level of concern	1
Secondary/Indirect/Synergistic Effects - influence on PPL potential	N/A	0
- influence on VOC/NO_x ratio	N/A	0
- influence on stratospheric ozone	not an ODC	0
- influence on global warming	not a precursor	0
- spatial (transboundary) transport	small contribution to nearby downwind areas	1
- influence on acid deposition potential	not a primary precursor	0
Human Health - level of carcinogenic effect	not a carcinogen	0
- level of non-carcinogenic effect (dose response relationships, comparison to thresholds, synergisms, etc.)	concentration low but measurable, synergisms with sulfates could produce some effects	1
Mitigation - timing/focus of mitigation vs. timing/focus of effects	effect continues throughout study period (>5 years) - study assumes no additional mitigation beyond standard construction and operation practices	3

ODC = Ozone Depleting Chemical, MAAC = Maximum Allowable Ambient Concentration, TLV = Threshold Limit Value

Table D.42: Significance Rating for AFB Level PM_{10}

Factors	Factor Weighting (a) High importance = 3 Medium importance = 2 Low importance = 1	Cumulative Effect Intensity (b) Large Adverse = 3 Moderate Adverse = 2 Small Adverse = 1 No Adverse Effect or Beneficial Effect = 0	Weighted Effect (axb)
<u>Pollutant Emissions</u>			
% change in emission level	2	3	6
timing, duration, and rate of change	2	3	6
comparison to emission limitations (% noncompliance)	2	0	0
<u>Ambient Air Quality Standards</u>			
change in ambient concentration	2	1	2
timing, duration, and rate of change	2	1	2
violation of standards	3	0	0
influence on air pollution episodes	2	0	0
influence on current area classification	2	0	0
<u>Public Perception</u>			
level of public concern	3	1	3
<u>Secondary/Indirect/Synergistic Effects</u>			
influence on PPL potential	2	0	0
influence on VOC/NO_x ratio	2	0	0
influence on stratospheric ozone	1	0	0
influence on global warming	1	0	0
spatial (transboundary) transport	2	1	2
influence on acid deposition potential	2	0	0
<u>Human Health</u>			
level of carcinogenic effect	2	0	0
level of non-carcinogenic effect	2	1	2
<u>Mitigation</u>			
timing/focus of mitigation vs. timing/focus of effects	2	3	6
			Total = 29

Table D.43: Significance Rating for Total Study Area PM_{10}

Factors	**Factor Weighting (a)** High importance = 3 Medium importance = 2 Low importance = 1	**Cumulative Effect Intensity (b)** Large Adverse = 3 Moderate Adverse = 2 Small Adverse = 1 No Adverse Effect or Beneficial Effect = 0	**Weighted Effect (axb)**
Pollutant Emissions			
% change in emission level	2	1	2
timing, duration, and rate of change	2	2	4
comparison to emission limitations (% noncompliance)	2	0	0
Ambient Air Quality Standards			
change in ambient concentration	2	1	2
timing, duration, and rate of change	2	1	2
violation of standards	3	0	0
influence on air pollution episodes	2	0	0
influence on current area classification	2	0	0
Public Perception			
level of public concern	3	1	3
Secondary/Indirect/Synergistic Effects			
influence on PPL potential	2	0	0
influence on VOC/NO_x ratio	2	0	0
influence on stratospheric ozone	1	0	0
influence on global warming	1	0	0
spatial (transboundary) transport	2	0	0
influence on acid deposition potential	2	0	0
Human Health			
level of carcinogenic effect	2	0	0
level of non-carcinogenic effect	2	1	2
Mitigation			
timing/focus of mitigation vs. timing/focus of effects	2	2	4
			Total = 19

Table D.44: Significance Rating for AFB Level CO

Factors	**Factor Weighting (a)** High importance = 3 Medium importance = 2 Low importance = 1	**Cumulative Effect Intensity (b)** Large Adverse = 3 Moderate Adverse = 2 Small Adverse = 1 No Adverse Effect or Beneficial Effect = 0	**Weighted Effect (axb)**
Pollutant Emissions			
% change in emission level	2	2	4
timing, duration, and rate of change	2	2	4
comparison to emission limitations (% noncompliance)	2	0	0
Ambient Air Quality Standards			
change in ambient concentration	2	0	0
timing, duration, and rate of change	2	0	0
violation of standards	3	0	0
influence on air pollution episodes	2	0	0
influence on current area classification	2	0	0
Public Perception			
level of public concern	3	1	3
Secondary/Indirect/Synergistic Effects			
influence on PPL potential	2	0	0
influence on VOC/NO_x ratio	2	0	0
influence on stratospheric ozone	1	0	0
influence on global warming	1	0	0
spatial (transboundary) transport	2	1	2
influence on acid deposition potential	2	0	0
Human Health			
level of carcinogenic effect	2	0	0
level of non-carcinogenic effect	2	1	2
Mitigation			
timing/focus of mitigation vs. timing/focus of effects	2	2	4
			Total = 19

Table D.45: Significance Rating for Total Study Area CO

Factors	**Factor Weighting (a)** High importance = 3 Medium importance = 2 Low importance = 1	**Cumulative Effect Intensity (b)** Large Adverse = 3 Moderate Adverse = 2 Small Adverse = 1 No Adverse Effect or Beneficial Effect = 0	**Weighted Effect (axb)**
<u>Pollutant Emissions</u>			
% change in emission level	2	1	2
timing, duration, and rate of change	2	2	4
comparison to emission limitations (% noncompliance)	2	0	0
<u>Ambient Air Quality Standards</u>			
change in ambient concentration	2	0	0
timing, duration, and rate of change	2	0	0
violation of standards	3	0	0
influence on air pollution episodes	2	0	0
influence on current area classification	2	0	0
<u>Public Perception</u>			
level of public concern	3	1	3
<u>Secondary/Indirect/Synergistic Effects</u>			
influence on PPL potential	2	0	0
influence on VOC/NO_x ratio	2	0	0
influence on stratospheric ozone	1	0	0
influence on global warming	1	0	0
spatial (transboundary) transport	2	0	0
influence on acid deposition potential	2	0	0
<u>Human Health</u>			
level of carcinogenic effect	2	0	0
level of non-carcinogenic effect	2	1	2
<u>Mitigation</u>			
timing/focus of mitigation vs. timing/focus of effects	2	2	4
			Total = 15

Table D.46: Significance Rating for AFB Level VOCs

Factors	Factor Weighting (a) High importance = 3 Medium importance = 2 Low importance = 1	Cumulative Effect Intensity (b) Large Adverse = 3 Moderate Adverse = 2 Small Adverse = 1 No Adverse Effect or Beneficial Effect = 0	Weighted Effect (axb)
Pollutant Emissions			
% change in emission level	2	1	2
timing, duration, and rate of change	2	2	4
comparison to emission limitations (% noncompliance)	2	0	0
Ambient Air Quality Standards			
change in ambient concentration	2	0	0
timing, duration, and rate of change	2	0	0
violation of standards	3	0	0
influence on air pollution episodes	2	0	0
influence on current area classification	2	0	0
Public Perception			
level of public concern	3	1	3
Secondary/Indirect/Synergistic Effects			
influence on PPL potential	2	1	2
influence on VOC/NO_x ratio	2	1	2
influence on stratospheric ozone	1	0	0
influence on global warming	1	0	0
spatial (transboundary) transport	2	1	2
influence on acid deposition potential	2	0	0
Human Health			
level of carcinogenic effect	2	0	0
level of non-carcinogenic effect	2	1	2
Mitigation			
timing/focus of mitigation vs. timing/focus of effects	2	2	4
			Total = 21

Table D.47: Significance Rating for Total Study Area VOCs

Factors	**Factor Weighting (a)** High importance = 3 Medium importance = 2 Low importance = 1	**Cumulative Effect Intensity (b)** Large Adverse = 3 Moderate Adverse = 2 Small Adverse = 1 No Adverse Effect or Beneficial Effect = 0	**Weighted Effect (axb)**
Pollutant Emissions			
% change in emission level	2	1	2
timing, duration, and rate of change	2	2	4
comparison to emission limitations (% noncompliance)	2	0	0
Ambient Air Quality Standards			
change in ambient concentration	2	0	0
timing, duration, and rate of change	2	0	0
violation of standards	3	0	0
influence on air pollution episodes	2	0	0
influence on current area classification	2	0	0
Public Perception			
level of public concern	3	1	3
Secondary/Indirect/Synergistic Effects			
influence on PPL potential	2	1	2
influence on VOC/NO_x ratio	2	1	2
influence on stratospheric ozone	1	0	0
influence on global warming	1	0	0
spatial (transboundary) transport	2	0	0
influence on acid deposition potential	2	0	0
Human Health			
level of carcinogenic effect	2	0	0
level of non-carcinogenic effect	2	1	2
Mitigation			
timing/focus of mitigation vs. timing/focus of effects	2	2	4
			Total = 19

Table D.48: Significance Rating for AFB Level NO_x

Factors	Factor Weighting (a) High importance = 3 Medium importance = 2 Low importance = 1	Cumulative Effect Intensity (b) Large Adverse = 3 Moderate Adverse = 2 Small Adverse = 1 No Adverse Effect or Beneficial Effect = 0	Weighted Effect (axb)
Pollutant Emissions			
% change in emission level	2	3	6
timing, duration, and rate of change	2	2	4
comparison to emission limitations (% noncompliance)	2	0	0
Ambient Air Quality Standards			
change in ambient concentration	2	0	0
timing, duration, and rate of change	2	0	0
violation of standards	3	0	0
influence on air pollution episodes	2	0	0
influence on current area classification	2	0	0
Public Perception			
level of public concern	3	1	3
Secondary/Indirect/Synergistic Effects			
influence on PPL potential	2	3	6
influence on VOC/NO_x ratio	2	0	0
influence on stratospheric ozone	1	0	0
influence on global warming	1	0	0
spatial (transboundary) transport	2	1	2
influence on acid deposition potential	2	1	2
Human Health			
level of carcinogenic effect	2	0	0
level of non-carcinogenic effect	2	1	2
Mitigation			
timing/focus of mitigation vs. timing/focus of effects	2	2	4
			Total = 29

Table D.49: Significance Rating for Total Study Area NO_x

Factors	Factor Weighting (a) High importance = 3 Medium importance = 2 Low importance = 1	Cumulative Effect Intensity (b) Large Adverse = 3 Moderate Adverse = 2 Small Adverse = 1 No Adverse Effect or Beneficial Effect = 0	Weighted Effect (axb)
<u>Pollutant Emissions</u>			
% change in emission level	2	1	2
timing, duration, and rate of change	2	2	4
comparison to emission limitations (% noncompliance)	2	0	0
<u>Ambient Air Quality Standards</u>			
change in ambient concentration	2	0	0
timing, duration, and rate of change	2	0	0
violation of standards	3	0	0
influence on air pollution episodes	2	0	0
influence on current area classification	2	0	0
<u>Public Perception</u>			
level of public concern	3	1	3
<u>Secondary/Indirect/Synergistic Effects</u>			
influence on PPL potential	2	1	2
influence on VOC/NO_x ratio	2	0	0
influence on stratospheric ozone	1	0	0
influence on global warming	1	0	0
spatial (transboundary) transport	2	0	0
influence on acid deposition potential	2	1	2
<u>Human Health</u>			
level of carcinogenic effect	2	0	0
level of non-carcinogenic effect	2	1	2
<u>Mitigation</u>			
timing/focus of mitigation vs. timing/focus of effects	2	2	4
			Total = 19

Table D.50: Significance Rating for AFB Level SO_x

Factors	Factor Weighting (a) High importance = 3 Medium importance = 2 Low importance = 1	Cumulative Effect Intensity (b) Large Adverse = 3 Moderate Adverse = 2 Small Adverse = 1 No Adverse Effect or Beneficial Effect = 0	Weighted Effect (axb)
<u>Pollutant Emissions</u>			
% change in emission level	2	2	4
timing, duration, and rate of change	2	2	4
comparison to emission limitations (% noncompliance)	2	0	0
<u>Ambient Air Quality Standards</u>			
change in ambient concentration	2	0	0
timing, duration, and rate of change	2	0	0
violation of standards	3	0	0
influence on air pollution episodes	2	0	0
influence on current area classification	2	0	0
<u>Public Perception</u>			
level of public concern	3	1	3
<u>Secondary/Indirect/Synergistic Effects</u>			
influence on PPL potential	2	0	0
influence on VOC/NO_x ratio	2	0	0
influence on stratospheric ozone	1	0	0
influence on global warming	1	0	0
spatial (transboundary) transport	2	1	2
influence on acid deposition potential	2	1	2
<u>Human Health</u>			
level of carcinogenic effect	2	0	0
level of non-carcinogenic effect	2	1	2
<u>Mitigation</u>			
timing/focus of mitigation vs. timing/focus of effects	2	2	4
			Total = 21

Table D.51: Significance Rating for Total Study Area SO_x

Factors	**Factor Weighting (a)** High importance = 3 Medium importance = 2 Low importance = 1	**Cumulative Effect Intensity (b)** Large Adverse = 3 Moderate Adverse = 2 Small Adverse = 1 No Adverse Effect or Beneficial Effect = 0	**Weighted Effect (axb)**
<u>Pollutant Emissions</u>			
% change in emission level	2	1	2
timing, duration, and rate of change	2	2	4
comparison to emission limitations (% noncompliance)	2	0	0
<u>Ambient Air Quality Standards</u>			
change in ambient concentration	2	0	0
timing, duration, and rate of change	2	0	0
violation of standards	3	0	0
influence on air pollution episodes	2	0	0
influence on current area classification	2	0	0
<u>Public Perception</u>			
level of public concern	3	1	3
<u>Secondary/Indirect/Synergistic Effects</u>			
influence on PPL potential	2	0	0
influence on VOC/NO_x ratio	2	0	0
influence on stratospheric ozone	1	0	0
influence on global warming	1	0	0
spatial (transboundary) transport	2	0	0
influence on acid deposition potential	2	1	2
<u>Human Health</u>			
level of carcinogenic effect	2	0	0
level of non-carcinogenic effect	2	1	2
<u>Mitigation</u>			
timing/focus of mitigation vs. timing/focus of effects	2	2	4
			Total = 17

Table D.52: Weighted Effects Comparisons for Air Quality Cumulative Effects

Pollutant	AFB Rating	Total Study Area Rating
CO	19	15
VOC	21	19
NO_x	29	19
SO_x	21	17
PM_{10}	29	19

Note: Possible range of values -- 0 - 35 (low significance or nonsignificant)
36 - 72 (moderate degree of significance)
73 - 108 (high level of significance)

applied to the predicted emissions. Even though the overall effect not significant, if air quality mitigation was intended, the NO_x and PM_{10} emissions might be appropriate focal points for those efforts.

The significance rating matrix was designed generically for widespread application. For this particular application, some data was not available. For example, in all but one case (PM_{10}), no ambient concentration information was available for use in the "Ambient Air Quality Standards" portion of the matrix. Ambient data was not available due to the lack of monitoring stations in the area. Discussions with state environmental regulators led to the conclusion that there were no ambient concentrations of concern relative to the unmonitored pollutants. Comparisons of available ambient data were made to national standards (see Table D.53) since the state and local standards were not more restrictive. Additionally, permit compliance status of the local industrial sources is confidential information. Since this can not be interpreted as an indication of total compliance or partial noncompliance, no assessment of percentage of noncompliance with permits could be made for the total area. The base was determined to be in compliance with all permit limitations.

Public concern was evaluated by interviewing the city and base personnel responsible for public meetings on development issues. The environmental office in the Civil Engineer Squadron was contacted for public opinions on base development issues and the city planning office was contacted for public opinions on the total area development. Both offices stated that the public has expressed very little concern over air quality issues; however, the topic is occasionally broached. Human health data obtained for application to this assessment is presented in Tables D.54 through D.59.

Table D.53: National Ambient Air Quality Standards for Criteria Pollutants (adapted from U.S. Environmental Protection Agency, 1996; U.S. Environmental Protection Agency, 1997a; U.S. Environmental Protection Agency, 1997b)

Pollutant	Primary Standard (Health Based)
Carbon Monoxide	35 ppm (40 mg/m^3) (1-hour average) 9 ppm (10 mg/m^3) (8-hour average)
Nitrogen Dioxide	0.053 ppm (100 μg/m^3) (annual average)
Sulfur Dioxide	0.14 ppm (365 μg/m^3) (24-hour average) 0.03 ppm (80 μg/m^3) (annual average)
Hydrocarbons (nonmethane)	0.24 ppm (160 μg/m^3) (3-hour average, 3-9 a.m.)
Lead	1.5 μg/m^3 (annual maximum quarterly average)
Particulates:	
PM_{10}	150 μg/m^3 (24-hour average, 99th percentile form)) 50 μg/m^3 (annual average)
$PM_{2.5}$	65 μg/m^3 (24-hour average) 15 μg/m^3 (annual average)
Ozone	0.12 ppm (235 μg/m^3) (1-hour average) -- **OLD** 0.08 ppm (3-year average of annual 4th-highest daily maximum 8-hour concentration) -- **NEW**

Table D.54: Toxicity and Health Data for Carbon Monoxide (after Patnaik, 1992)

Carbon Monoxide (CO)
TLV-TWA = 50 ppm
Acute toxic symptoms of exposure include headache, tachpnea, nausea, dizziness, weakness, confusion, depression, hallucination, loss of muscular control, and heart rate and respiratory increase followed by decrease. At high doses, the effects continue with collapse, unconsciousness, and death.

50 ppm (prolonged exposure)	No adverse health effects
100 ppm (6-hour exposure)	Perceptible symptoms
5000 ppm (5-minute exposure)	Death

Table D.55: Toxicity and Health Data for Hydrocarbons (adapted from U.S. Department of Health, Education, and Welfare, 1970b; Patnaik, 1992; and American Conference of Governmental Industrial Hygienists, 1986)

Aliphatic and Alicyclic Hydrocarbons have very low toxicities. The gaseous compounds are nontoxic but are simple asphyxiants. At very high concentrations, these gases can be narcotic.

Aliphatic Hydrocarbons	No effect reported at levels below 500 ppm
Alicyclic Hydrocarbons	No effect reported at levels below 500 ppm

Mononuclear aromatic hydrocarbons exhibit low acute toxicity. Inhalation of high concentrations can cause narcosis with symptoms such as hallucination, excitement, euphoria, distorted perception, and headache. Benzene is the only mononuclear aromatic that is a possible human carcinogen. Several polynuclear aromatic hydrocarbons (PAHs) can cause cancer, however, the oral toxicity of PAHs is low to very low.

Examples:

Benzene
TLV-TWA = 10 ppm
Suspected Human Carcinogen
Acute Toxicity is low. Acute symptoms (200 ppm) are hallucination, distorted perception, euphoria, somnolence, nausea, vomiting, and headache. High concentrations may cause convulsions. Five to ten minute exposure at 2% in air can cause death. Chronic exposure is more severe than acute effects. Target organs for acute and chronic effects are blood, bone marrow, central nervous system, respiratory system, eyes, and skin. Heavy exposure can cause bone marrow depression, anemia, and leukemia.

Toluene
TLV-TWA = 100 ppm
Acute toxicity is low. Acute symptoms (200 ppm) are excitement, euphoria, hallucination, hallucination, distorted perceptions, confusion, headache, and dizziness. Higher concentrations can produce depression, drowsiness, and stupor. Inhalation of 10,000 ppm may cause death. The chronic effects are lower that for benzene. It is not known to cause anemia or bone marrow depression. It is not known to cause cancer.

Asphalt Fumes - native mixture of hydrocarbons.
TLV-TWA = 5 mg/m^3
Animal studies have not provided sufficient evidence of asphalt induced lung cancer.

Table D.56: Toxicity and Health Data for Nitrogen Oxides (adapted from Shy and Love, 1980; U.S Environmental Protection Agency, 1982; and Patnaik, 1992)

Nitrogen Dioxide (NO_2)
TLV-TWA = 3 ppm
Highly toxic gas. It is an irritant to the eyes, nose, throat, and respiratory system. Symptoms include cough, frothy sputum, chest pain, dyspnea, congestion, inflammation of the lungs, and cyanosis.

0.5 ppm (healthy subjects and subjects with asthma or bronchitis)	No significant changes in pulmonary function
0.62 ppm (healthy subjects)	No significant change in cardiovascular or pulmonary function after 15, 30, or 60 minutes of exercise
1.0 ppm (healthy subjects)	No change in pulmonary function
0.5 - 1.5 ppm (chronic bronchitis subjects)	No increase in airway resistance
1.6 - 2.0 ppm (chronic bronchitis subjects)	Significant increase in airway resistance
2.5 ppm (healthy subjects)	Significant increase in airway resistance without altering arterialized oxygen pressure
2 - 5 ppm (healthy subjects)	Increase in airway resistance
5 ppm and above (healthy subjects)	Increase in airway resistance and impaired transport of gases between blood and the lungs
200 ppm (1-2 minute exposure)	Death

Table D.57: Toxicity and Health Data for Sulfur Oxides (after U.S. Department of Health, Education, and Welfare, 1969b; Patnaik, 1992; and American Conference of Governmental Industrial Hygienists, 1986)

Sulfur Dioxide (SO_2) TLV-TWA = 2 ppm Exposure can cause severe irritation to the eyes, skin, mucus membranes, and respiratory system. Effects of exposure include coughing, choking, suffocation, bronchoconstriction, and skin burn. Additionally, studies have shown synergistic effects when combined with smoke* or particulates. *Patnaik (1992) defines smoke as small particulate matter of diameter 0.05 - 1.0 μm	
5-13 ppm	Increased respiratory flow resistance
1000 ppm (10 minute exposure)	Death
Synergisms	
115 μg/m^3 (0.04 ppm) (annual mean) with smoke concentration of 160 μg/m^3	Increase in mortality from bronchitis and lung cancer can occur
120 μg/m^3 (0.046 ppm) (annual mean) with smoke concentration of 100 μg/m^3	Increase in frequency and severity of respiratory disease in children may occur
105 - 265 μg/m^3 (0.037 - 0.092 ppm) (annual mean) with smoke concentration of 185 μg/m^3	Increase in frequency of respiratory symptoms and lung disease may occur
600 μg/m^3 (0.21 ppm) (24-hour mean) with smoke concentration of 300 μg/m^3	Accentuation of symptoms may occur in patients with chronic lung disease
715 μg/m^3 (0.25 ppm) (24-hour mean) with particulate matter	Sharp increase in illness rates for severe bronchitis patients over age 54 may occur
300 - 500 μg/m^3 (0.11 - 0.19 ppm) (24-hour mean) with low particulate matter	Increased hospital admission of older persons for respiratory disease may occur
500 μg/m^3 (0.19 ppm) (24-hour mean) with low particulate matter	Increased mortality rates may occur
SO_2 concentration at 715 μg/m^3 (0.25 ppm) (24-hour mean) with smoke concentration of 750 μg/m^3	Increased daily death rate may occur
1500 μg/m^3 (0.52 ppm) (24-hour mean) with particulate matter measured as a soiling index of 6 cohs (coefficient of haze) or greater	Increased mortality may occur

Table D.58: Toxicity and Health Data for Particulates (adapted from U.S. Department of Health, Education, and Welfare, 1969a and Patnaik, 1992)

Particulates TLV-TWA = 10 mg/m^3 (nuisance dusts) Toxic effects of nuisance particulate dusts are insignificant. Symptoms of exposure include irritation to eyes and nasal passages. Synergisms between particulates and sulfur oxides produce additional effects.	
80 - 100 $\mu g/m^3$ (annual geometric mean) with sulfation levels of 30 mg/cm^2-mo.	Increased death rate for persons over 50 years of age may occur
above 100 $\mu g/m^3$ (annual geometric mean) with sulfation levels above 30 mg/cm^2-mo.	Increased death rate for persons over 50 years of age are likely
100 - 130 $\mu g/m^3$ (annual mean) with SO_2 concentration greater than 120 $\mu g/m^3$ (annual mean)	Children are likely to experience increased instance of respiratory disease
above 200 $\mu g/m^3$ (24-hour average) with SO_2 concentration greater than 250 $\mu g/m^3$ (24-hour average)	Increased illness in industrial workers may occur
above 300 $\mu g/m^3$ (24-hour average) with SO_2 concentration greater than 630 $\mu g/m^3$ (24-hour average)	Chronic bronchitis patients will suffer acute worsening of symptoms
at or above 750 $\mu g/m^3$ (24-hour average) with SO_2 concentration at or above 715 $\mu g/m^3$ (24-hour average)	Excess deaths and a considerable increase in illness may occur

Table D.59: Toxicity and Health Data for Ozone and Photochemical Oxidants (adapted from U.S. Department of Health, Education, and Welfare, 1970a; Patnaik, 1992; and American Conference of Governmental Industrial Hygienists, 1986)

Ozone TLV-TWA = 0.1 ppm Chronic exposure may result in pulmonary disease	
0.2 ppm or below	No effect
0.3 ppm	Threshold for nasal and throat irritation
0.5 - 1.5 ppm	20% volume decrease in forced expiratory volume
2 ppm, 9 ppm	Pulmonary congestion
100 ppm (1-hour exposure)	May cause death
Photochemical Oxidants (general)	
Long term exposure to ambient air with peak oxidant periods exceeding 0.5 ppm	Increased respiratory flow resistance in guinea pigs
Long term exposure to irradiated auto exhaust with oxidant levels from 0.2 to 1.0 ppm	Decrease in fertility, an increase in neonatal mortality, and a stress adaptation in mice

STEP 8 -- MITIGATION OPPORTUNITIES

Opportunities for mitigation can be determined and evaluated by applying the method discussed in Chapter 5. Since the primary influence on air quality occurs during the construction stage of the activities presented in this example, it would be appropriate to focus mitigation attention on construction procedures and construction equipment emission control. However, since it was determined that there would be no significant effect on air quality resulting from these development activities, it may be prudent to focus additional mitigation resources on environmental resources other than air quality.

OBSERVATIONS AND CONCLUSIONS

This case study has presented an application of the proposed methods to a real world example. The intent was to validate the previously proposed methods as well as to demonstrate the practicalities of air quality CEA. This study presents the details and assumptions of each step of the analysis. Presentation in this format demonstrates the value of the assessment methods in context with their limitations in real world application.

Once this type of study has been conducted for a specified region, it can be incorporated into the formal development planning documents of both the city and the federal installation. Current practice in development planning recommends a section discussing the environmental resources of the planned area. The Air Force has included such discussions in its comprehensive development planning documents as have city planning agencies. The addition of a CEA component into these documents seems logical and desirable.

Once the CEA study is formalized, either as a section of a comprehensive plan or as a separate document, it can be referenced in project-specific environmental impact studies conducted on the included activities. These project-specific studies may lead to environmental assessments (EAs) or environmental impact statements (EISs). If new project proposals are planned, the CEA can be easily updated to incorporate the relevant effects. When conducting the individual project assessments, the requirements for CEA can be adequately addressed by discussing only the relevant quantitative and qualitative results, their influence on significance determinations, and the additional mitigation opportunities as determined here. The net result would be a more complete NEPA document (either an EA or EIS) for the project proposal without a noticeable increase in volume.

The CEA study should be reviewed and updated on a time schedule appropriate to the development planning pace of the assessed area. Open communication between the federal agency planning office and the city planning office can facilitate the time schedule necessary to ensure updates are performed adequately.

In summary, this study has provided a practical example of the application of a step-wise approach for cumulative air quality effects. To that end, the following observations and conclusions can be drawn:

(1) This analysis represents only one piece of an overall CEA addressing all media. It is intended to be maintained as an independent document or possibly an appendix to a community development plan. It will require periodic updates as conditions change or new information is obtained, possibly on an annual or biennial basis. And, it is envisioned that the results of this study would be incorporated by reference into each relevant EA or EIS.

(2) Assessors should not restrict themselves to following the exact order of the method steps. The step sequences are intended to guide the assessor's thought processes, not dictate the chronology of step applications. It can be useful to revisit steps as new information becomes available.

(3) Quantitative analysis results can shift the focus with respect to the pollutant of concern when the spatial or temporal context is varied.

(4) Caution should be used when applying average, or surrogate, correction factors when calibrating dispersion models. This approach can introduce an additional potential for error that may limit the value of the resultant predictions.

(5) Projections of activity proposals and their effects become increasingly more uncertain as the future time boundary is extended. Firm commitments to development activities far into the future is rare, and to estimate emissions from uncertain future proposals can lead to inaccuracies in future emission levels or ambient air quality concentrations. However, failure to include these more speculative possibilities can lead to the erroneous conclusion that emission levels will decline in the future. Regardless of the approach taken, the assessor should be aware of the probability that far reaching future plans will likely be modified as the timeframe draws closer.

(6) Public participation can be directly incorporated into this analysis process during the application of the factor weights and effects intensity ratings. By default, public involvement is also incorporated in this analysis through its inclusion in the development process of any community planning documents utilized, and during the individual project EIA process for each activity that incorporates this analysis.

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